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| | **VAN**<br>***FP6/2004/IST/NMP/2 - 016696 VAN***<br>***Virtual Automation Networks*** |

Work Package 1

# Requirements and Trend Screening

Task 1.3

# Trend Screening and Self evaluation

# Key Applications and Benchmarking

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# Executive summary

This report belongs to the first set of VAN project deliverables and aims for the mission and vision of VAN project related technologies. The document is closely connected with the demonstration activities in WP 9 “Validation and Test” and the requirements tasks in WP1. The core or technology packages are also implicitly embedded along the whole document.

The topics of this report are Key Applications and Benchmarking. With regard to Key Applications, these are real (and planned) examples of how VAN technologies can perform jointly a solution for the diverse industry problems in real scenarios. The other topic is Benchmarking, in this document is used in the sense of a collection of different aspects for every *Key Application* that must be evaluated to check the enhancements or advantages contributed by the VAN technology.

A description of the Key Applications is performed through a general introduction of the Industry process (what is to be manufactured or produced and how). Next, a scenario description (scenario here refers to a setting for a work) is presented and for each Key Application, a set of use cases (use case is a specific example of usage, and is characterised by an actor, and different objects).

Two Key Applications are presented to the reader, one coming from the Manufacturing field “Heterogeneous Manufacturing Cells” and another one coming from the Process Industry “Distributed Bio-Power Stations”.

In order to achieve a detailed description of the applications, several use cases are detailed. This Information is directly derived from the end users (MCM, FIDIA and AUCOTEAM) expertise. Moreover, the selected use cases cover almost all possible communication levels in Automation/Process.

From the point of view of VAN Demonstrators[1], this is an example of how different requirements from end-users (industry) are being targeted by VAN wide approach:

- Secure remote access: Telecontrol is economically advantageous both for the end user and for the machine builder.
- Real-Time connection of different plants: decentralized (via WAN or LAN) plant management matches the requirements of industry).
- Connection between Numerical Control (henceforward NC) and low level peripherals: there is always a need to standardise ”heterogeneous components" from the end user point of view.
- Reconfigurability of robotic systems fixtures: the reconfigurability of manufacturing cells is imposed by the aggressive competition of emerging countries.

Finally, a Benchmarking table resumes the actors, advantages expected from VAN technology, and the indicators that will be used to measure these advantages.

For Process Industries (and Energy Production) another "Key Application" has been selected: Distributed Bio Power Stations. This application is outlined to show several different processes involved and the relevance of the control techniques that VAN technology will allow (Central Control and Maintenance of multiple power stations).

An overview of the process industry is presented and focused on the bio power stations. After that, the application of VAN solutions to these power stations is explained from the Aucoteam’s point of view. The need for a central supervisory, model based control, training, co-ordination and maintenance is the trigger to apply VAN philosophy to a number of bio power stations.

Three use cases are described within this demonstrator:

[1] Demonstrator is a physical realization (prototype model) of the key application on which the introduced use cases can be verified.

- Process stabilisation; compensation of correctable disturbances.
- Process optimisation; remote setting of control parameters to optimise performance criteria.
- Safety control; to prevent unacceptable process states.

The detailed description of the application includes the current architecture and how this architecture should be adapted to the VAN technology. Besides, the security requirements are of paramount importance and different security threats are taken into account in order to be assessed.

The use cases are focused on the reaction to failures and fluctuations of the different inputs, and the use of Telecontrol solutions in the application.

Finally, the conclusions obtained and the future work are presented at the end of the document.

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# 1 Introduction

In order to establish a precise focus for the VAN project, this deliverable presents scenarios as a working principle in order to get a better hold in the long-term objectives of the project. Furthermore, these scenarios must give a clear view of what VAN project is aiming for regarding the general public and other target audiences such as industry or university.

The Key Applications will represent a basis to investigate the requirements, and are going to be defined in details. On the other hand, the selection of Key Applications is one of the results of the first milestone of the VAN project.

Benchmarking is the other main topic of this deliverable. There are several meanings for this term coming, for example, from the management field as “best practice benchmarking” or from the computer field as “the result of different test programs”.

The aim of Benchmarking in this document is to try to focus the main contributions and advantages of the VAN technology into selected scenarios and use cases.

## 1.1 Methodology

There follows an explanation on the methodology chosen for this deliverable. A limited number of real applications have been chosen, then, real everyday scenarios within the selected applications are described. With the aid of the Demonstrator partners of the consortium, the current status of these scenarios and the requirements from the VAN technology are presented. A top-down methodology has been used starting from a general description of the application field, next, example applications are presented, and finally a scenario with different use cases is defined in details.

To select the Key Applications different criteria have been taken into account:

- The application must exploit different aspects of the VAN architecture.
- The application needs the VAN technology in order to enhance the current performance, or create new opportunities.
- The application must belong to a key industrial sector for the EU.
- Application selected from different industrial sectors (Manufacturing, Process, Energy).

Next, to complete the description, a section called Benchmarking table presents a summary table with the different indicators that will be used in each use case, for every Key Application.

A graphical description of this methodology is presented in Fig. 1

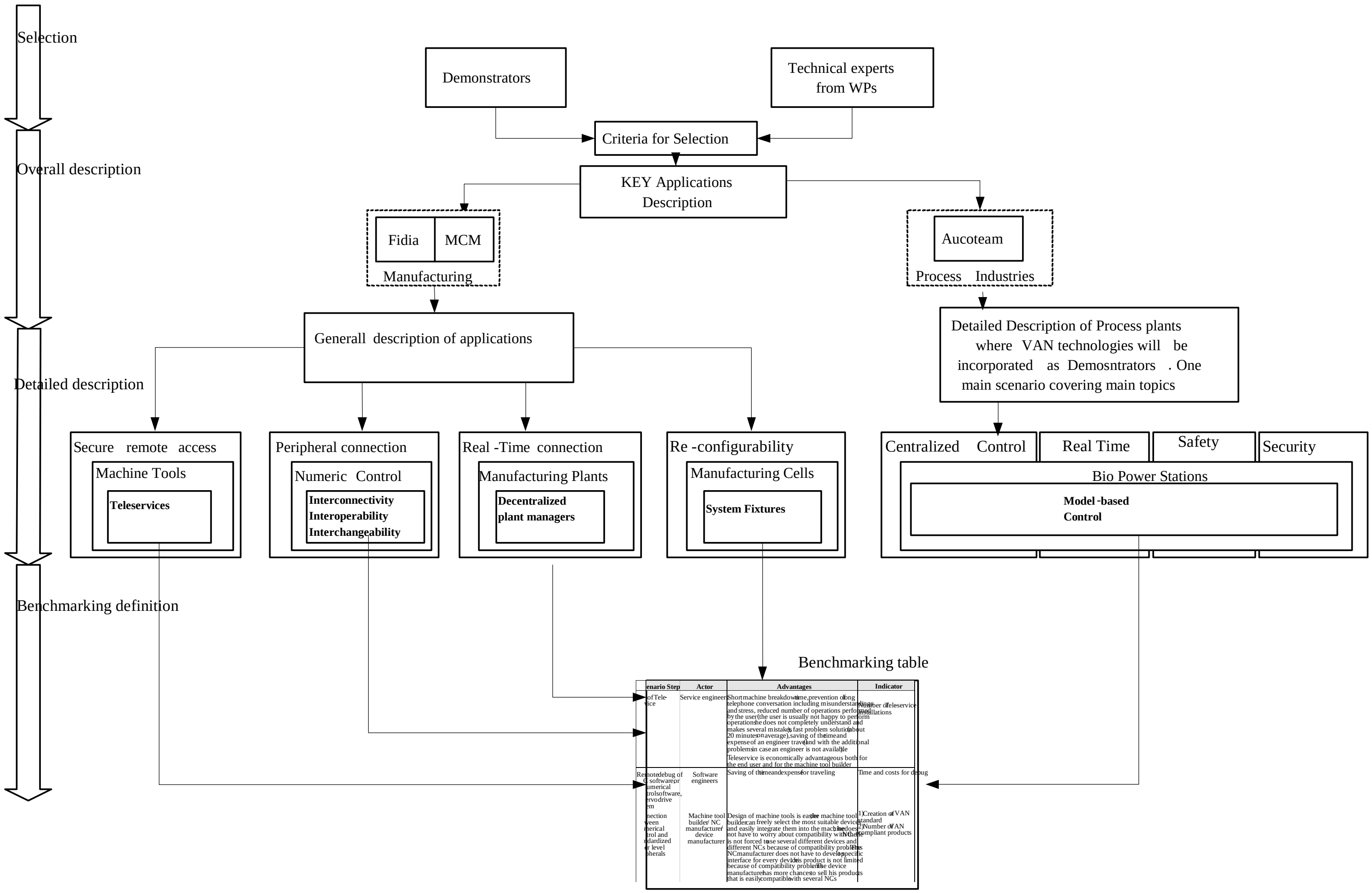


Fig. 1 Flowchart Methodology

# 2 Heterogeneous manufacturing cells

## 2.1 Introduction

This chapter describes a Key Application where machine tools and automation devices are used for the production of parts. This can apply to different kinds of industrial sectors; the most common are:

- Automotive (production of motor parts)
- Aerospace
- Moulds and dies; these tools are also used in different kinds of industrial sectors; for instance:
    - Automotive (production of car body parts or plastic parts)
    - Shoes
    - Plastic objects (bottles, ski boots, luggage, …)

There are several reasons to consider this application as key:

- It is a kind of application where the advantages of the VAN architecture are particularly clear;
- It is a widespread industrial case; thus it can assure high visibility of the results;
- The economical advantages resulting from the VAN architecture are particularly significant;
- All the main topics treated by VAN are included: wireless, Real-Time, safety, security.

This kind of industrial plants can have totally different configurations; some examples are shown in the following figures:

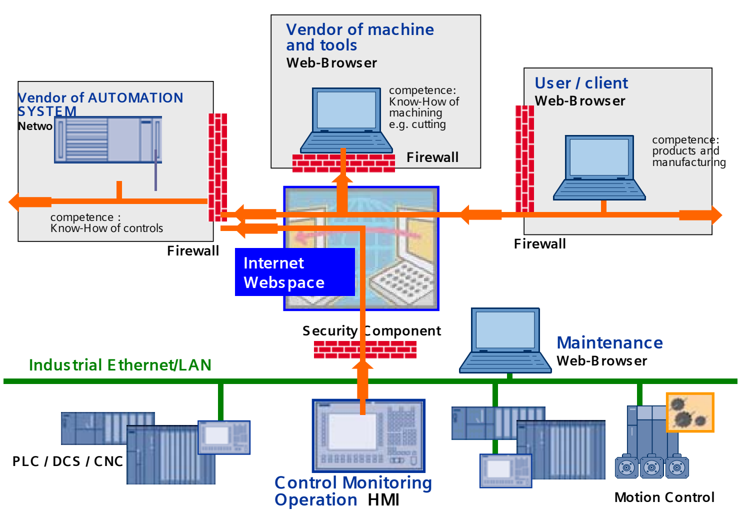


Fig. 2 Manufacturing Cell Application Example

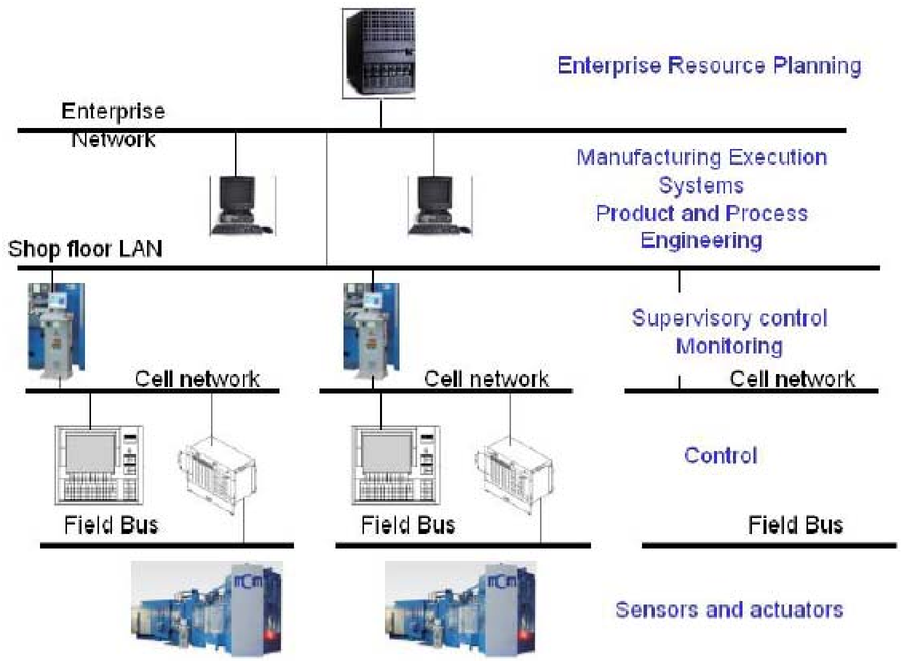


Fig. 3 Manufacturing Cell Application Hierarchy

These plants may have 1 (like in Fig. 2) or several (like in Fig. 3) hierarchical levels. The common characteristic is the presence of one (or more) Local Area Networks (LAN) where several automation devices are connected. These devices may be:

- Robots, with their own control system
- Machine Tools, with their own control system
- Devices controlled through a PLC system
- Personal Computers to be used for display and/or as a supervisor system for a lower hierarchical level
- Intelligent devices including their own control system
- Single servo drive systems
- Sensors, I-O modules, and so on

On a lower hierarchical level, control systems are usually required to interface:

- servo drives
- digital I-O signals, analog I-O signals, handwheels,…
- sensors (accelerometers, thermometers)
- PLC systems.

In many cases the LAN can be connected through modem and telephone line or through Internet to a Wide Area Network (WAN); this network may be used, for instance, for connection to the site of the machine tool manufacturer, or numerical control manufacturer, or servo drive manufacturer or generic device manufacturer. Many applications are already available that allow to remotely control the system, look at the NC display, system parameters, log file, and so on. But although technologically feasible in the state-of-the-art, this connection (that is potentially extremely helpful) is not used because of security problems. The secure solutions provided by VAN will allow to overcome these problems.

Fig. 4 shows an example of state-of-the-art potential telecontrol application: several PCs at customer site (in most of current control system a PC is used for running the Human to Machine Interface of the control system, so these PCs represent control systems) are connected through LAN to a modem. On the other side a Remote Access Server allows connection to local PCs. This way the HMI of control systems at customer site can be connected and handled remotely by PCs in the Machine Tool Builder site.

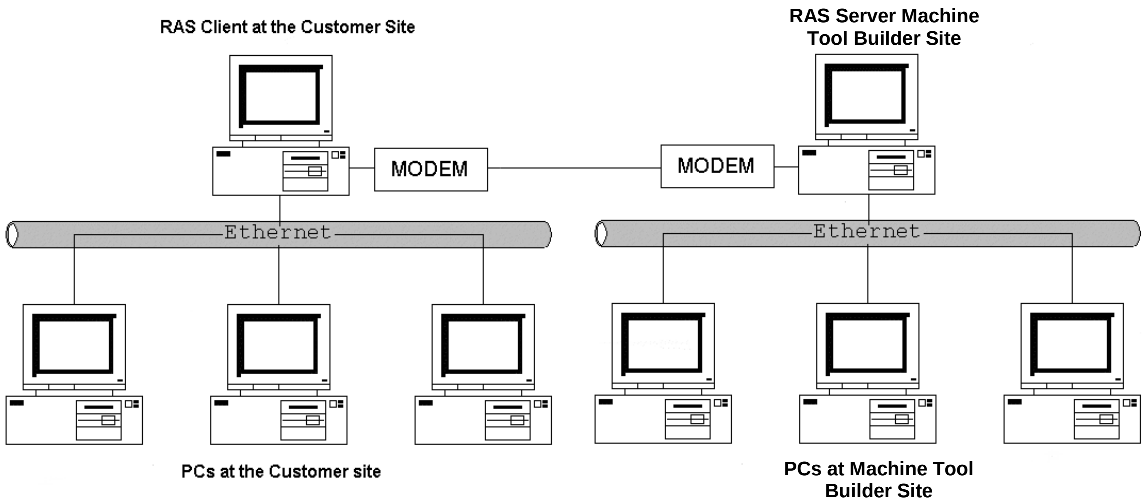


Fig. 4 State-of-the-art telecontrol architecture

## 2.2 Description of the key application[2]

[2] Please, see comparison of safety and security on chapter 5.1, page 17 of the Deliverable D01.3-1V2 "Trend Screening Report on VAN Relevant Technologies Version 2"

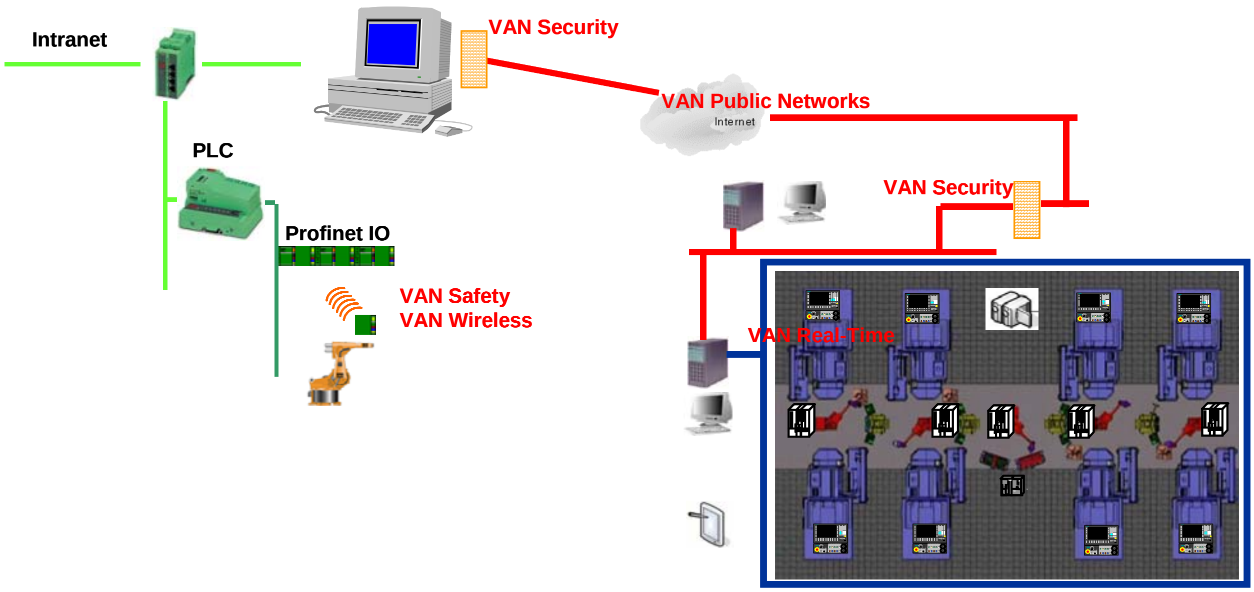


Fig. 5 Example of application

Fig. 5 shows an example of application: two industrial plants make complementary productions. They should be synchronised through the connection to a public network, because the resulting products have to be assembled in a following phase. In the figure one plant is drawn through a robot commanded through a PLC system, and the other plant through a set of machine tools with robots moving parts from one machine to the other.

This application emphasizes several advantages coming from the VAN approach:

1. In many cases the traditional, centralized manufacturing system approach does not work anymore; this occurs in cases where the manufacturing plant often changes. In case of manufacturing cells, for instance, each one is a unique one. Reconfiguration takes place often, because for instance some machines are moved from one cell to another one, or machines (measuring machine, robots…) are added. This causes big difficulties. Another big problem is the optimised configuration of the plant.

   These reasons are pushing towards a decentralized approach for the machines and their control systems that would make reconfiguration easier.

   The target for many manufacturers is to design very highly automated manufacturing plants that use robots for load-unload pieces to pallets, pallets to machine tables, and so on. The typical scenario is a focused flexibility plant: a plant that produces a limited number of parts that anyhow change in time, so it has to be reconfigured from time to time. The interest of such applications is in the reconfiguration of the automation part, and the target is to use the results of VAN to simplify this approach.

2. In many cases in the state-of-the-art the physical connection of control systems to the WAN is not present, because manufacturers are afraid of intrusions into their network. In fact part-programs that are present in the NC are considered as very important and valuable company know-how. In case of an automobile industry, for instance, they show the appearance of next models of cars. As a consequence end users are ready to adopt each possible solution to prevent outside people from accessing files on the NC hard disk, even the extreme solution of not connecting it to the WAN. Of course this solution brings as a disadvantage the

impossibility to use telecontrol solutions. A secure connection would allow removing this kind of extreme security policy, and as a consequence would allow a wide spreading of telecontrol solutions.

3. The lack of standardization of devices is a huge problem today. The machine tool manufacturer would like to freely select the Numerical Control, motors, servo drives and other peripherals according to his preference. On the contrary it is constrained by the compatibility problems, since, for instance, a NC is only compatible with some kind of servo drives, and so on. Compatibility problems are mostly due to proprietary network protocols that are very different from one device to another one, and very often not documented.

## 2.3 Use cases

### 2.3.1 Secure remote access

As already explained in previous chapters, in many cases in the state-of-the-art, the physical connection of control systems to the WAN is not present, because manufacturers are afraid of intrusions into their network. As a consequence, telecontrol solutions cannot be used most of times. But a secure connection, provided by the VAN platform, will allow the connection between control systems and the site of the machine tool manufacturer, or device manufacturer through the Wide Area Network, and thus a wide spreading of telecontrol solutions.

This means that several applications allowing to remotely control the system, look at the NC display, system parameters, log file, and so on, may be started remotely.

**Scenario Description**

After the occurrence of a problem a customer calls and is connected to an engineer at NC builder site who looks into the logfile and NC parameters; this allows a fast and exact diagnosis of the problem, in some cases also a complete solving or at least a fast fixing from remote just by verifying and changing the values of some parameters.

Some examples:

1. After an optical scale transducer breakdown, the broken scale is substituted by the motor encoder just by changing a parameter from remote, and so the machine goes on working (even though in a degraded mode) until the part to be changed is delivered to the customer.
2. Problems due to a wrong tuning of system parameters or wearing out of components can be identified through remote connection. An engineer staying at NC builder site starts an application that performs some tests; after collecting data from sensors, this application elaborates them and calculates a set of indicators. By analyzing the results through his experience, an engineer can monitor the behavior of the machine tool, and decide if any mechanical component should be substituted, or modify the tuning of system parameters and repeat tests.

   Some examples of significant tests are:

   - Velocity step response
   - Linear interpolation between couples of axes
   - Circular interpolation between couples of axes
   - Current absorption during the movement.
3. Debug of PLC software, or of Numerical Control software, or servo drive system from remote.

The same operations may be performed in a scenario where VAN is not present either through long telephone conversation (causing misunderstandings and stress and production delays) or through the traveling of service engineers (causing costs and production delays).

**Economic considerations**

At present, when a machine tool breaks down at customer's site, or the customer finds a fault in the machine, he calls the Machine Tool Builder (henceforward MTB) Service Department. Sometimes the fault can be managed by telephone, sometimes a service engineer must be sent to the customer site. The customer can be located wherever in the world. A service engineer goes to the customer and tries to fix the problem, looking for the reason for the break down. If necessary he substitutes a broken part; in the end he restarts the machine. The cost for repairing a break down occurring at customer's site can be split in the following items:

- Cost for the intervention of a service engineer: this cost is paid by the MTB in case the system is under guarantee, or if the customer has stipulated a "Service Contract"; it is paid by the customer otherwise. The cost for the intervention can be evaluated between 120 and 400 € per day, depending on the length of the travel, and on the time spent for the real intervention. The cost of the "Service Contract" can be evaluated on average as 6000 € per year, double if the spindle is included.
- Cost for repairing the broken part: This cost can change quite a lot depending on the kind of part which has broken. This cost can range between 10 € (in case of a fuse) and 500 €, but in some special case it can reach even 1500 €.
- Unavailable machine tool cost: cost for the customer, who is not able to use the machine tool, which causes a money loss, and forces a reorganisation of his schedule. This cost changes very significantly according to the size of the machine tool, and to the value of parts it usually machines, so deviations can be enormous; on machine tools manufactured by Fidia, this cost can vary between 35 and 70 € per hour, so the average figure can be evaluated about 50 € per hour. On big size machines, or for machines that produce very high value parts, this cost can raise up to 100-150 € per hour. Moreover, very often end users have contracts with fees in case they are not able to meet the deadline: in this case they lose a percentage of their price for each delay day; but it is very difficult to quantify this loss.
- The average reparation time can be evaluated in the following way: a service engineer is able to be at the customer site usually the day following the break down. The intervention lasts on average half a day.

In case a Tele-service solution can be used, the number of physical interventions of service engineers can be decreased, which causes savings either on the MTB side (in case of guarantee or “Service Contract”) or on the end user side. In case of broken parts, of course the part has to be substituted, but a good diagnosis performed in remote mode may allow the job to be performed by the end user personnel. In case no part has to be substituted, a significant percentage of interventions may be cut. Of course the cost for repairing the broken part would not change, but the downtime would also decrease.

In conclusion, we can expect the following advantages:

- For end users:
  - Higher quality of Technical Assistance.
  - Lower Technical Assistance fees.
- For service:
  - Lower travelling and manpower costs for each intervention.

In case of Fidia, we can evaluate the economical advantage in the following way:

- Savings in Service: 10% means 70.000 € per year
- Increased sales because of increased performances: 2% means additional turnover = 126.000 € per year.

Moreover, the remote debug of PLC software or of Numerical Control software or servo drive system would cause savings of traveling costs still to be evaluated.

### 2.3.2 Connection between Numerical Control and standardized lower level peripherals

First of all, let us define some terms according with the IEC definitions:

- Interconnectivity: "*Two or more devices are interconnectable if they are using the same communication protocols, communication interface and data access".* That is, devices from different manufacturers can be safely connected to the same communication platform.
- Interoperability: "*Two or more devices are interoperable if they can work together to perform a specific role in one or more distributed applications. The parameters and their application related functionality fit together both syntactically and semantically. Interoperability is achieved when the devices support complementary sets of parameters and functions belonging to the same profile".* In other words, the ability to connect successfully elements from different suppliers.
- Interchangeability: "*Unlike the other compatibility levels (which refer to two or more devices working in the same system) interchangeability refers to the replacement of one device with another. Devices are interchangeable for a given role in a distributed application if the new device has the functionality to meet the application requirements".* Devices from one manufacture can be replaced with functionally equivalent devices from another manufacture..

The ultimate theoretical goal is interchangeability, but this is an extremely ambitious and delicate topic, also involving the inner behaviour of devices; for instance, for servo drives this means same physical, electromechanical, functional, interface,.... behaviour. In any case this is far beyond the scope of the VAN project.

The first goal of VAN will be interconnectivity, to be achieved through the standardization of communication protocols. The ultimate goal will be interoperability, to be achieved through the standardization of communication interface. It can only be achieved if the communication platform specifications are complete and a proper system testing and validation process is employed.

When VAN becomes a widely spread communication platform, all NC manufacturers, servo drives manufacturers and device manufacturers will produce VAN compliant products, with noticeable advantages for all of them.

**Scenario Description**

A machine tool manufacturer requests the manufacturer to interface a new kind of device. Supposing this device is VAN compliant, it can be very easily interfaced by the NC from the manufacturer; no development of a specific (hardware and software) interface is needed.

**Economic considerations**

Interoperability of devices will allow the Fidia NC to interface new servo drives and peripherals (including wireless sensors and other devices) that are not compatible today; the Fidia servo drives will be interfaced by different NCs, while they are today only compatible with Fidia NC. This can be expected to cause a significant increase in the sales of both products, that can be evaluated as:

- Increased sales of NCs: 3% means additional turnover = 159.000 € per year.
- Increased sales of servo drives: 10% means additional turnover = 100.000 € per year.

### 2.3.3 Real-Time connection of different plants

In the state-of-the-art different plants can be connected through the Internet, but no communication timing can be guaranteed. A strict synchronisation of different plants cannot take place.

**Scenario Description**

One of the two plants is forced to stop the production of a certain kind of parts (due to raw material not being available, or to one of the machines breaking down). The second plant gets the information by a few seconds, and can modify on-the-fly its production plan, in order to adapt to the first plant.

Reaction time is not necessarily very short (some seconds are a huge time from an electronic point of view), but the key feature is that response-time is guaranteed, which makes it a Real-Time application.

**Economic considerations**

This scenario would open totally new capabilities still unforeseen today. It is not possible at the moment to evaluate the relative huge economical impact.

### 2.3.4 Safety application over different plants

Safety communications over heterogeneous networks are nowadays not possible. This is part of the research focus in VAN. In order to test and benchmark the specification developed in WP5 the key application for safety is shown in Fig. 6.

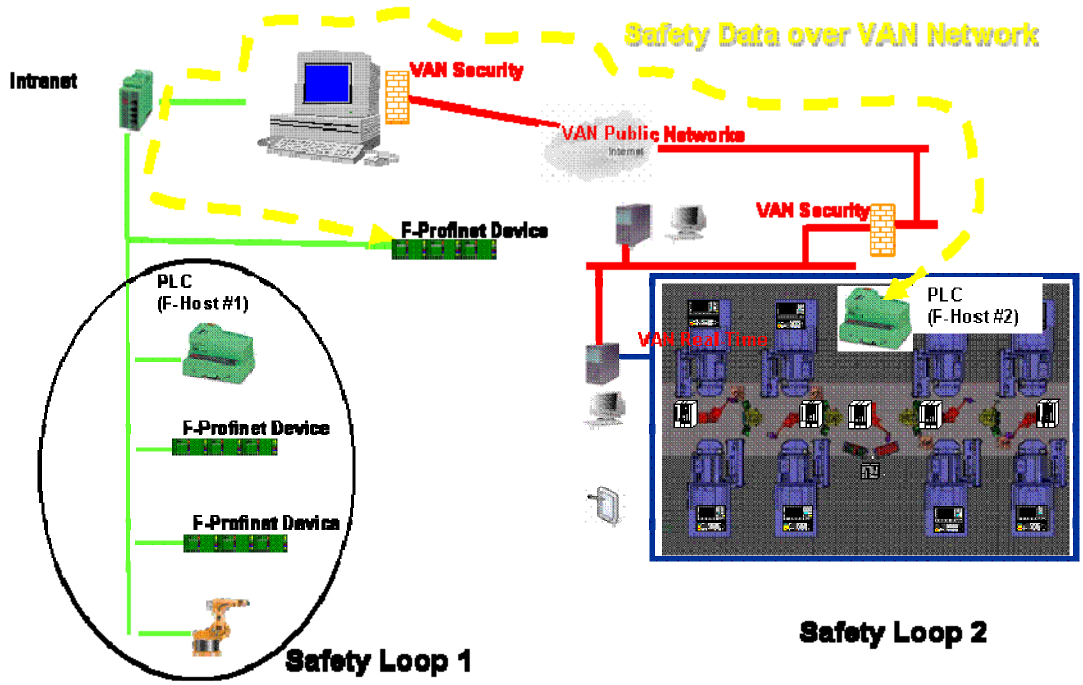


Fig. 6 Safety communication over different plants

Each factory side has its own safety loop for protecting human beings and machinery. A classical use-case is the emergency stop.

The transport of safety data over VAN networks is needed if direct dependencies between the two factory sides leading to potential hazardous situations exist. The reaction time, which is a critical figure for the availability of the plants, will be investigated together with the general real-time requirements. By installing the key application also the impact of the transmission errors within the VAN networks on the safety application will be measured.

### 2.3.5 Reconfigurability in manufacturing systems

A Manufacturing system is designed to produce product families defined from some general characteristics (material, dimension, production volumes, and geometric features).

During its expected lifetime counting 15-20 years it will be modified to adapt to new productions. On the other side product designer will try to adapt new products to the existing manufacturing capability of the enterprise. Traditional manufacturing strategy for highly dynamic market is to incorporate as much flexibility as possible. This is the case of the Flexible Manufacturing Systems (FMS). Over-dimensioning is no more an option with the new production cost structure imposed by the aggressive competition of emerging countries. This opens up the business case for reconfigurable manufacturing system. Reconfigurable Manufacturing Systems (RMS) follow a different strategy to cope with market dynamics. Instead of incorporating all the flexibility once at the beginning of their lifecycle, RMS are created by incorporating basic process modules — both hardware and software — that can be rearranged or replaced quickly and reliably.

Short ramp-up time after reconfiguration is a basic requirement for reconfigurable system (ramp-up time is the time necessary to produce high quality). Put in other words: every system can be reconfigured but only RMS provides a cost-effective reconfiguration process. Capabilities to develop systems that can economically adapt to frequent reconfiguration define new manufacturing strategies and require new approach in product/process engineering.

The use case for reconfigurability is strictly related to previous consideration.

**Scenario description**

In the scenario of reconfiguration of robotic systems fixing, the following steps take place:

- A new part type needs to be executed on the manufacturing system. This part type requires specific tools for the machining centre, specific fixtures for the robotized load/unload station and specific control programs for the entire control unit involved.
- At the end of current operations an operator asks to enter inside the manufacturing cell. When the system grants this right, putting control units in a safe state, the operator enter the manufacturing system off start removing old tools and fixtures and add the new one inside the manufacturing cell.
- Each tool and fixture is equipped by an RFID and the manufacturing system is capable to locate RFID inside its work area. After the physical reconfiguration, the operator using its personal assistant, a wireless PDA connected to the cell supervisory entity, send the command to start ramp-up phase.
- The supervisory control unit acquires ID and location of every tool and fixture and automatically updates the manufacturing cell layout.
- The robot control unit uploads the control program associated to the part type specified by the operator, from an enterprise repository and checks that the correct fixing has been configured.
- The machine unit uploads the process recipe associated to the new part type from an enterprise repository and checks if the correct tooling has been configured.
- The manufacturing system starts its operation.

This description represents by itself a relevant step forward in relationship to state-of-art and current factory practice. First of all if tooling (or setup) of machine tools is a well known and to some extend well supported activity, reconfiguration of robotic systems fixing is still an open issue. The scenario provide a safe approach to the execution of this activity.

The ramp-up time is the critical factor after reconfiguration activities that can change manufacturing strategies toward the real management of potential manufacturing system flexibility.

Reducing the ramp-up time means that the enterprise can reduce the minimum quantity to produce in an economically competitive way.

The ramp-up time, as previously stated, is the time necessary to produce high quality. Improving vertical integration between control layers, introducing sensorized fixtures and location aware identification systems, should reduce the overall ramp-up time of order of magnitude from days to hours.

**Economic considerations**

The complexity to measure flexibility and reconfigurability makes it difficult to justify the additional costs involved in achieving these properties and to clearly perform economic considerations on their effect on productivity and ROI.

Nevertheless in this scenario we concentrate on a specific measure for reconfigurability that is ramp-up time and hence we will try to develop some rough evaluation based on this measure.

A highly automated manufacturing system as the one presented in this scenario is normally operated 24/7 mostly unattended. In order to evaluate the cost differential related to cost reduction for reconfiguration activities it is necessary a rough estimation of the potential yearly income generated by such a system. Even if strongly related to machine type and operation complexity, an hourly rate of 50 € for machining operation can be assumed. With a prudential 80% efficiency over 20 daily hours, 5 days a week and 50 weeks per year (5.000 hours/year), the potential income for the 8 machines in the scenario can be estimated as 1.600.000 €.

Based on this figures it is possible to estimate reconfiguration cost for a single cell (2 machines) of the overall system.

With actual technology, and an estimation of 3 days of reconfiguration time (0% production rate for the reconfigured cell and 50% production rate for other cells) and 5 days ramp-up time (with production rate increasing linearly from 0% to the prudential throughput of 80% for the reconfigured cell), every reconfiguration means a direct lost of 14.200 €.

VAN technology could enable the reduction of this lost to a marginal 960 € (4 hours reconfiguration time and 16 hours for ramp up time, no influence on other machines).

Beyond figures, most of the advantages are at the strategic level. Being capable to reconfigure rapidly and cost-effectively could provide to the firm more flexibility in manufacturing strategies, and hence better capacity to catch market opportunities.

## 2.4 Benchmarking table

A table is presented as a summary of the presented use cases for the Manufacturing scenario, with the proposed indicators to be evaluated.

| Use case | Actor | Advantages | Indicator |
|---|---|---|---|
| Secure Remote Access | Service engineers | Short machine breakdown time, prevention of long telephone conversation including misunderstandings and stress, reduced number of operations performed by the user, fast problem solution (about 20 minutes on average), saving of the time and expense of an engineer travel. | 1) Number of Tele-service installations<br>2) Time for problem solution |
| Remote debug of PLC software, or of Numerical Control software, or servo drive system | Software engineers | Saving of the time and expense for traveling | Time and costs for debug |
| Connection between Numerical Control and standardized lower level peripherals | Machine tool builder / NC manufacturer / device manufacturer | Design of machine tools is easier; the machine tool builder freely selects the most suitable devices, easier integration into the machine; eliminates compatibility problems between devices and NCs. The NC manufacturer does not have to develop a specific interface for every device. The device manufacturer has more chances to sell his products that are easily compatible with several NCs. | 1) Creation of a VAN standard<br>2) Number of VAN compliant products |
| Re-configurability of robotic systems fixtures | Factory personnel: operator responsible for reconfiguration, process engineers. | To provide a safe approach to the execution of tooling (or setup) of machine tools.<br>The reduction of the ramp-up time can reduce the minimum quantity to produce in a economically competitive way. | Ramp-up time. |
| Real-Time connection of different plants | Decentralized plants managers | Production of far-away plants can be synchronized. The relative production adapt one to the other. No big stocks of produced parts are forced to wait. | Communication time between the 2 plants |
| Safety Application over different plants | Decentralized plants managers | Safety critical information, which can lead to hazardous situations in one of the plants and origins in the other plant, is immediately available in the possible reaction times. | Safe communication time between the 2 plants |

Table 1 Benchmarking table for the Manufacturing Key Applications

# 3 Distributed bio power stations

## 3.1 Introduction into process control

### 3.1.1 Typical properties of the process industry

Process industry is a generic term to describe all kinds of continuous processes existing in the industry. Typical processes are for example:

1. Chemical processes
2. Biotechnological processes
3. Generation and distribution of energy
4. Waste disposal and recycling
5. Water supply and waste water detoxification

From the point of view of automation and control the specific properties of process industry (Different from the manufacturing industry) are:

- Continuous processes
- Control tasks are defined as compensation of correctable and uncorrectable disturbances ( Stabilization, optimization, safety control )
- Control activities in the case of disturbances only,

Different from the process industry specific properties of manufacturing industry are:

- the machines cannot operate without the control system
- the control systems are an integrated part of machines
- Continuous activities of control systems, not only in the case of disturbances

For the VAN-project we have to describe the typical properties of the technological processes in the process industry from the point of process control. For this purpose the so called Phase-Model of Production can be used.

Monitoring and control functions relating to certain product and/or process properties must be carried out in each process element. Product and process properties are the object classes of information about the process.

Process properties are the following:

- State variables such as pressure, temperature, and concentration. The process can be described in terms of these or with derived state functions.
- Process parameters such as heat-transfer coefficient and catalyst activity. These identify the constraints under which the process runs. Process parameters are stationary or at least quasi-stationary quantities.
- Control variables. These characterize intervention in the process.

Product properties are the following:

- Physical quantities
- Chemical quantities

- Technological properties
- Product indicators

Product properties and process properties can be represented in the control and monitoring system as a stream of information of property profiles accompanying the material stream in the phase-model (see Fig. 7).

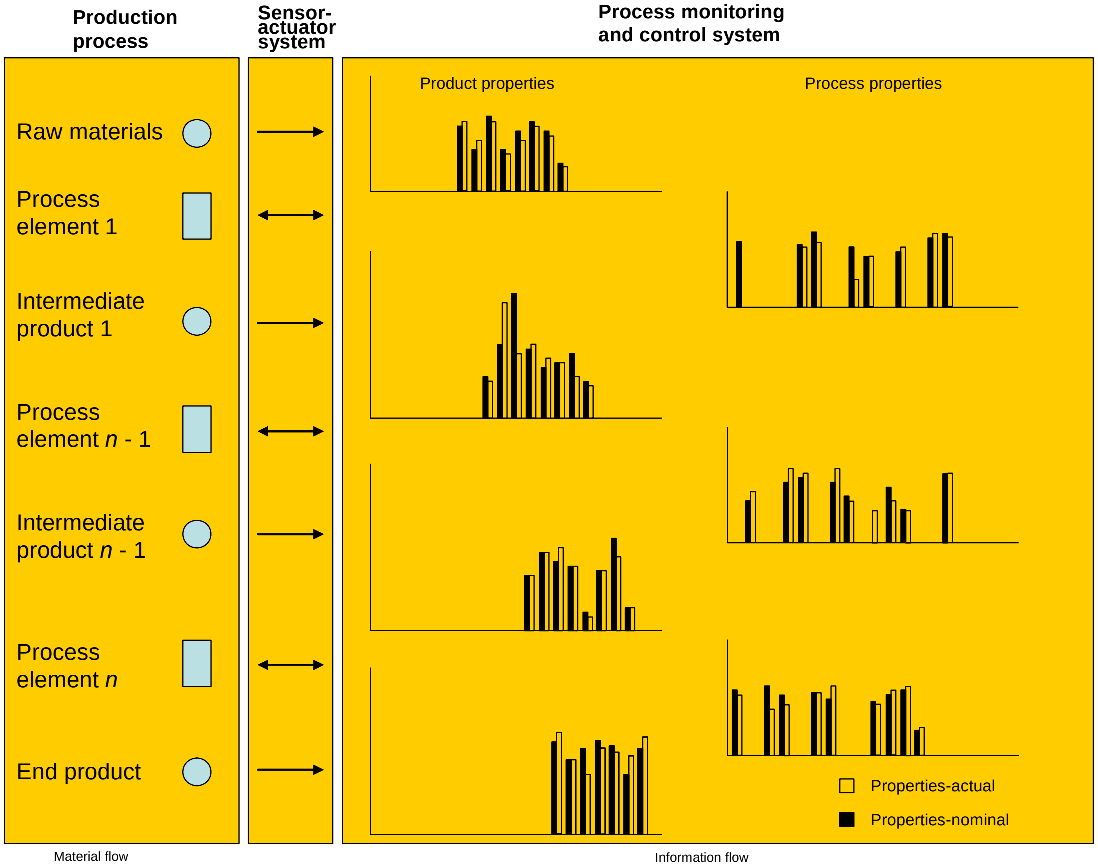


Fig. 7 Profiles for process and product properties

As nominal values, they are an essential part of the production instructions. As actual values, they are used in process control, process analysis, and quality assurance. Process engineering is customarily concerned with the material flow (and the energy flow, although this is not illustrated here) in a production operation, whereas the task of process control engineering is to deal with the information flow. The crosslink between the material flow and the information flow is provided by sensors and actuators. Sensor technology acquires the information required for process monitoring and control. The function of actuator technology is to derive actions on the process from information extracted from the information stream.

### 3.1.2 Reasons for a key application

Within the process industry the bio power stations are selected as a Key Application of the VAN project. This kind of power stations, have all typical properties of technological processes in the process industry. The reasons for a Key Application are:

- The structure and the components of the VAN-based central control and maintenance system for geographical distributed bio power station can be used for other plants of the process industry.
- The economical advantages resulting from the VAN solutions are significant, the raising of profit is about 20% (see table 6)..

- The following topics of VAN project are included: Real-time, wireless, engineering.

### 3.1.3 General approach to the application of VAN solutions

In Fig. 8 the general approach to the application of VAN solutions in the process industry is presented.

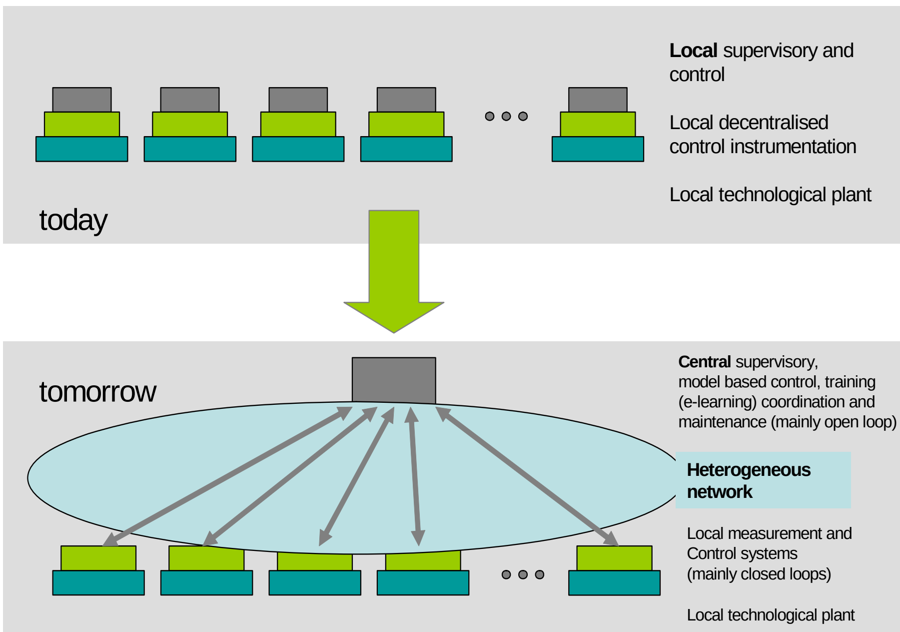


Fig. 8 General approach to the application of VAN Solutions in the process industry

This general approach leads to the hierarchical structure of the central control and maintenance system for geographical distributed bio power stations (Fig. 9). The symbol marks the influence of VAN elements in the prototypical solution (Demonstrator).

The control system is a two level system:

- local measurement and control system (mainly closed loop)
- central control system including maintenance and operator training (mainly open loop)

The central control system consists of stationary part (Model based control, knowledge based maintenance, training) and of a mobile part (Mobile control stations).

Model based control means the definition or calculation of control variables using the mathematical model of control subject. Model based training means the training of operators using the real existing control and monitoring system connected with the model of control subject. The development of models for control, maintenance and training are not focus of VAN-Project.

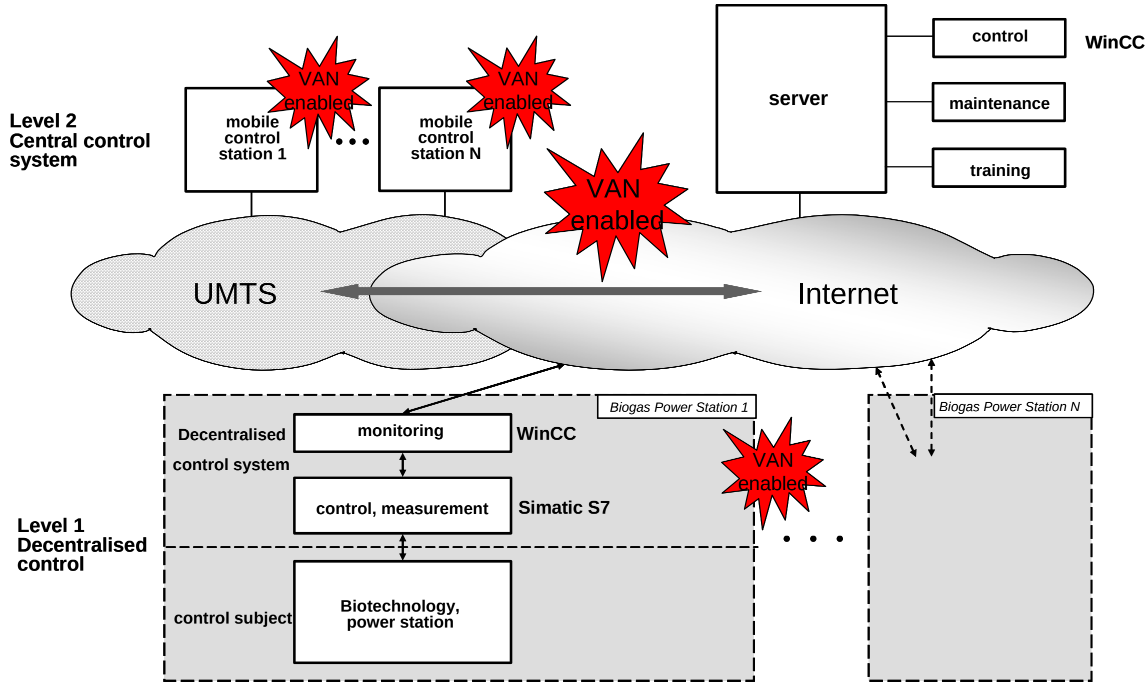


Fig. 9 Central Control and Maintenance for geographical distributed bio power stations

### 3.1.4 Description of control subject

The WABIO[3] Bio power stations (Fig. 10) are the control subject.

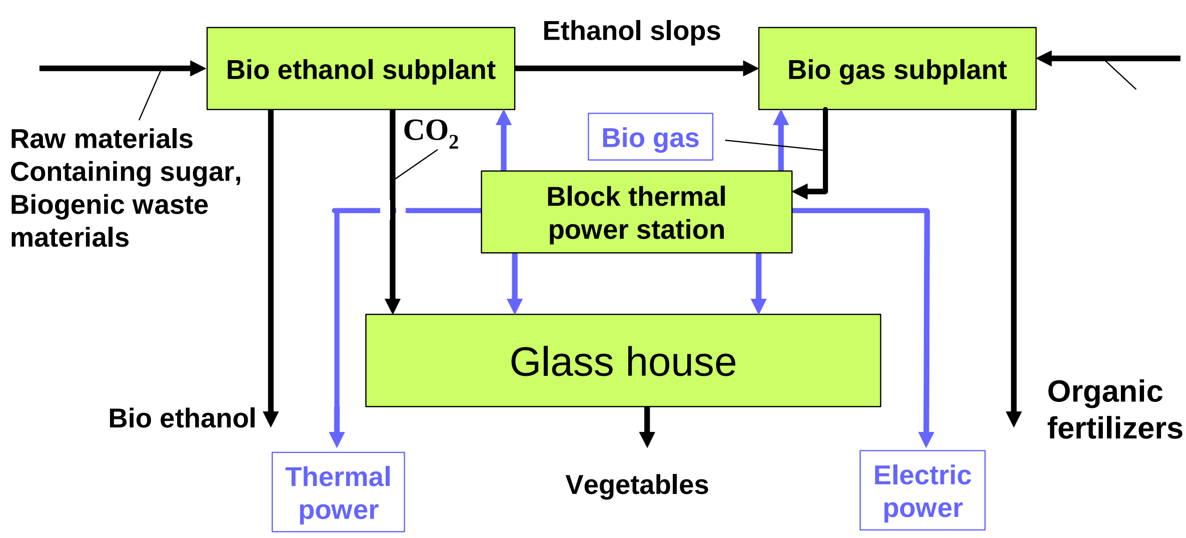


Fig. 10 General technological structures of WABIO bio power station (Control subject)

For the operation of bio power station the big problem is the fluctuation of quality and quantity of input materials (raw materials, waste). In order to compensate this disturbances a model based control system for process coordination is necessary.

[3] WABIO® is a technical process based on anaerobic digestion of organic materials that obtains several outputs like electric power or bio ethanol.

WBIO Bio Power stations are centres that produce bio-energy and Bio fuels (ethanol), based on selected biogenic waste materials and raw materials containing sugar and starch. Components (subplants) of Bio Power stations are:

- production of bio-ethanol
- vegetable production in glasshouses, using heat that comes up and gaseous carbon dioxide
- fermentation of bio gas (methane).
- production of organic fertilizers
- hot cooled technology of block thermal power stations to deliver surplus energy (electric and heat power)
- production of liquid carbon dioxide

The preferred waste to put in WABIO Bio power stations is:

- waste coming from agriculture, horticulture, managing of ponds, forestry, hunting and fishing
- waste coming from the preparation and treatment of meat, fish and further foods made from animals
- waste coming from the preparation and treatment of fruit, vegetable, grain, food oil, cacao, coffee, tea
- waste coming from manufacture of milk products
- waste coming from manufacture of bakery and sweet products
- waste coming out from distillation process

To estimate the benefit of using VAN solutions the economic data of the bio power station (Table 2) are very important. Using VAN solution the owners of bio power station expect firstly increase of turnover and of cash flow and secondly a reduction of workers.

| Economic object | Economic data |
|---|---|
| investment volume: | 12 … 14,5 million € |
| workers (without glass house) | 10 … 12 persons |
| workers (with glass house) | 26 … 32 persons |
| | |
| turnover | 8 … 9,5 million € yearly |
| from this | |
| Bio fuels | 2,5 … 5 million € yearly |
| Carbon dioxide | 1,5 … 2,5 million € yearly |
| vegetables | 0,7 … 0,9 million € yearly |
| fertilizer | 0,4 … 1,5 million € yearly |
| electric power | 2,7 … 4,8 million € yearly |
| thermal power | 0,3 … 0,5 million € yearly |
| | |
| Cash flow | 4,0 … 5,5 million € yearly |

Table 2 Economic data sheets of WABIO Bio power station

The prognostic economic data of the WABIO Bio power station are one example for the efficient implementation of VAN solutions. A rapid growth of biogas power plants in Europe and a positive marked trend has been established in the fields of use and generation of biogas. Most of the biogas power stations are located in the agricultural sector and from the economic point of view central located Process Control Service Centres are very useful.

With the background of the expected market trend in the field of biogas production:

| | | | |
|---|---|---|---|
| - power from biogas | 2005 | 2% | of the total power market |
| | 2010 | 6% | |
| | 2030 | 16% | |
| - biogas power stations (Investment) | 2005 | 4 billion € | |
| | 2010 | 10 billion € | |
| | 2030 | 32 billion € | |
| **- Investment share of control and monitoring systems** | **10% (Possible with VAN-Solutions only, heterogeneous networks are the prerequisite)** | | |

Table 3 - Results of market research in Europe

VAN based solutions are very important for the installation of the centralised control and monitoring systems for decentralised biogas power stations.

## 3.2 Description of the key application

Fig. 11 shows the structure and the components of an example of application (Demonstrator). The intension is to carry out in the future a real VAN-based system for the central control of three geographical distributed bio power stations. This architecture is a concrete form of Fig. 10 for one Bio power station with its central control. The connection between the supervisory control and the centralised control is implemented via UMTS and Internet. In the example of application the decentralised control system (Fig. 10) consist of the control level and monitoring level (Fig. 11).

The decentralised control system includes SCADA-System and 11 PLCs (Siemens Simatic S7). There is a remote-maintenance station with an ISDN-Modem. The technological level consists of 3 subplants.

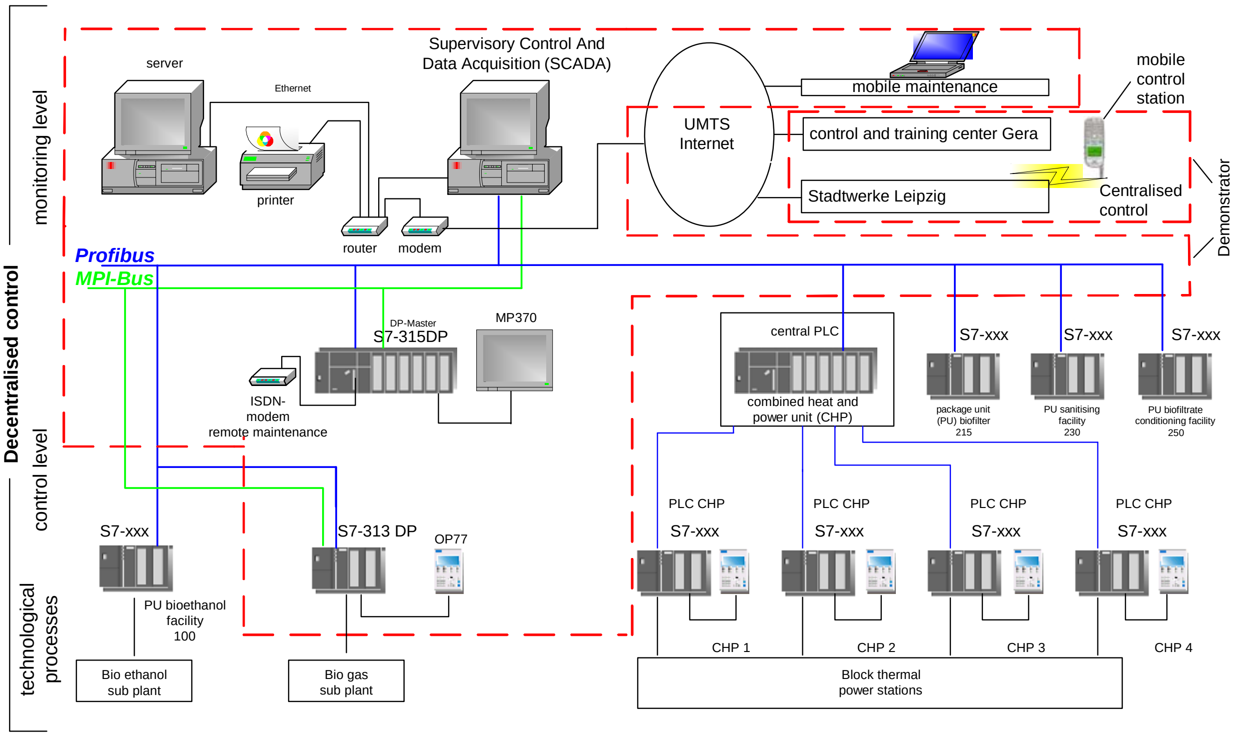


Fig. 11 Control and monitoring structure of the biotechnological plant.

The process interface of the bio power station consists of:

- 200 sensors (for example: Temperature, PH, level)
- 100 actors (for example: pumps, valves)

The recommendations (requirements) regarding transmission are:

- Transmission rate between central control station and bio power station – 300 bit/sec.
- Transmission time for full presentation of process situation – 15 min.

These recommendations are in accordance with the real-time requirements. The transmission of the full process information must be carried out the first time only. After this the changes of process situation must be transmitted only.

This application emphasizes the following customer benefits (Advantages) of centralized control of distributed technological plants using heterogeneous networks (VAN-solutions):

- The know- how of one operator or maintenance engineer can be used for the control of a great number of plants without time-delay
- The Model based control system can be used for a great number of plants
- The costs of centralized control system can be divided in the number of decentralized technological plants
- Integration of operator training systems (OTS) in the centralized control system
- estimated benefit in the waste industry (for the example bio power stations) - 30% raising of the profit

## 3.3 Use cases

### 3.3.1 Process control tasks (scenarios)

The aim of the central control of distributed bio power stations is to compensate the disturbances (fluctuations of quantity and quality of input materials) using algorithms of process coordination (Table 4).

| Process coordination control task and control algorithm (Scenarios) | Real-time requirements |
|---|---|
| Process stabilization:<br>Compensation of correctable disturbances with the aim of holding the process parameters constant at specified values | Soft real-time (open loop)<br>Hard real-time (closed loop) |
| Process optimization:<br>Determination and setting of control variables so as to optimize a specified criterion while complying with specified restrictions | Soft real-time |
| Safety control<br>Compensation of uncorrectable disturbances with the aim of preventing unacceptable process states and product qualities or of minimizing their consequences | Hard real-time |

Table 4 Process co-ordination tasks

The time data (maximal dead time) can be found in Table 6.

The content of Table 4 is the description of process coordination control tasks and the real-time requirements.

### 3.3.2 Safety requirements

The algorithm for the safety control consists of 2 steps:

1. Recognition of dangerous or unacceptable situation in the technological plant including the automation system.
2. Carrying out the safety function for preventing unacceptable deviations in the process, in the process control, or in the process monitoring and control hardware from the nominal state.

Safety functions do not intervene in the sequence of events under normal operating conditions and permit the process control functions to perform their task. Before a deviation enters the unacceptable range, the safety functions are activated, interrupting the access of the process control functions.

Typical safety functions are interlocking for functional units and STOP conditions in sequence controls.

A sample use case for VAN-based safety loop control via public network in the process industry is shown in Fig. 12. The central safety loop controller contains the safety application. One or more safety I/O-devices are installed in decentralised other plants. The safety loop will be realised VAN-based via public networks (“virtual safety loop”).

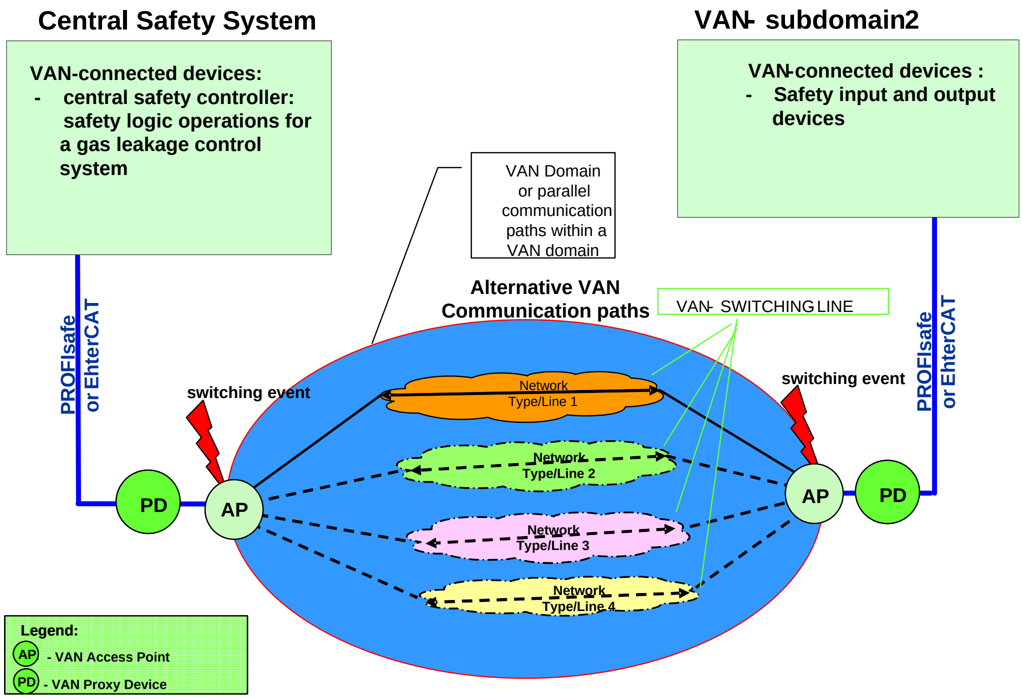


Fig. 12 - Example test scenario for process industry - Safety loop control

### 3.3.3 Evaluation of security requirements

Our aim is the division of VAN based control and monitoring system in following Security Integration Zones (SIZ):,

**outward zone:** with external access, SIZ-3

**middle zone:** operator functions as a “mediator” inward and outside (e.g. VPN gateway), SIZ-2

**internal zone:** on-line closed loop automation functions, extremely secured, SIZ-1

It is to define the Security structure for the following automation levels:

- Remote functions.
- Engineering and monitoring.
- closed-loop Control functions.

Table 5 describes the possible impacts of the security threats to the security integration zones.

| Threat | Possible impact to | | | Reasons/Comments |
|---|---|---|---|---|
| | SIZ1 | SIZ2 | SIZ3 | |
| **Denial of Service ( DoS)** | - | - | X | Server required |
| **Distributed Reflection Denial of Service ( DRDoS)** | - | - | X | Server required |
| **Ping flood** | (X) | (X) | (X) | Direct network access required |
| **Amplifier Network** | - | - | X | SIZ1 is not connected to public networks |
| **SYN-Flood** | - | X | X | Connection to public networks required |
| **Land Attack** | - | X | X | Connection to public networks required |
| **IP Spoofing** | - | X | X | Connection to public networks required |
| **Replay attack** | - | - | X | Server required |
| **Man in the middle** | (X) | X | X | In SIZ 1 for radio based connections only |
| **Pre-Attack Probe (PAP):** | - | - | X | Server required |
| **Virus** | - | (X) | X | Low risk for non standard operation systems |
| **Computer worm** | - | (X) | X | Low risk for non standard operation systems |
| **Trojan Horse** | - | (X) | X | Low risk for non standard operation systems |
| **Buffer overflow** | - | X | X | Connection to public networks |
| **Mail bombing** | - | - | - | Mail systems are not integrated in process control structures |
| **Backdoor** | - | X | X | Low risk for non standard operation systems |
| **Sniffing** | (X) | (X) | (X) | Direct network access required |
| **Message injection** | - | - | - | Must be prevented by VAN tools |
| **Code injection** | - | - | - | Must be prevented by VAN tools |
| **Message delay** | - | - | X | Server required |
| **Password cracking** | (X) | (X) | (X) | Direct network access required |

Table 5 Possible impact of the security threats to the security integration zones

The security integration zones (SIZ) and the security structure must be checked and evaluated using attack-tools on the basis of the possible security threats (see Table 5).

One of the most important goals of the project is increasing security attributes of heterogeneous automation networks.

### 3.3.4 Real–time requirements

Table 6 shows the real-time requirements regarding VAN-solutions for the presented Key Application. It is necessary to note that the max dead times don't depend on the type of communication.

| Application | | max Dead time |
|---|---|---|
| **Control subject** | **Control task** | |
| Bioreactors (Part of Biogas subplant) | optimization / stabilization | 10 s |
| | Safety control | 600 ms |
| Distillation columns (Part of Bioethanol subplant) | optimization / stabilization | 100 ms |
| | Safety control | 60 ms |
| Block terminal power station | optimization / stabilization | 5 s |
| | safety control | 100 ms |
| Tanks | stabilization | 100 s |
| Glass house | optimization | 200 s |
| Motors / pumps | Safety control | 400 ms |

Table 6 Timing requirements for control subjects and control tasks

### 3.3.5 VAN - Enhancement

The benefit of VAN-solutions depends on the disturbance amplitude and on the disturbance frequency. The VAN-Enhancement is shown in Table 7. The application field of VAN is shown.

| | | Distance between distributed Bio power station | | |
|---|---|---|---|---|
| **Properties of disturbances** | **Average frequency of control action** | **less than 5 km** | **more than 5 km** | **Raising of profit** |
| **Big amplitude and high frequency** | **One time per minutes** | **VAN necessary** | **VAN necessary** | **30%** |
| **Little amplitude and low frequency** | **One time per day** | **VAN limited necessary (desirable)** | **VAN necessary** | **20%** |
| **Extremely little amplitude and low frequency or no disturbances** | **One time per month** | **VAN not necessary** | **VAN not necessary** | **0%** |

**Prototypical solutions**

Table 7 VAN-Enhancement

## 3.4 Benchmarking table

The Table 8 presents the summary of the presented use cases for the Processing scenario, with the proposed indicators to be evaluated.

| Use Case | Actor | Advantages | Indicator |
|---|---|---|---|
| Reaction to failure (Break down) of plant sections | Operator | Model based system for control can be used, know how of one operator can be used for a great number of distributed plants without time-delay | Number of distributed plants, prevention of economic losses |
| Reaction to fluctuation of quality and quantity of input materials | Operator, Process-engineer | Model based control system for optimization and stabilization can be used, know how of one specialist can be used for a great number of plant without time-delay | Number of distributed plants |
| Telecontrol | Service-engineer | Know how of one service-engineer can be used for great number of distributed plant, saving of service time and costs | Time and costs for maintenance, prevention of failures (Break down) of subplants and of devices |

Table 8 Benchmarking table for the Processing Key Application

### 3.4.1 Future work

**Problems to be solved are:**

- Selection of existing tools and components (Engineering, operating)
- Selection of tools for the experimental analysis of QoS regarding security (for example attack tools)
- Transitions between sub networks (Interfaces)

**Requirements for VAN-Solutions in the Process industry:**

- To guarantee the desired end-to-end performance in heterogeneous LAN / WAN networks.
- To create the mechanisms and to select the tools for security with scalable security in different zones.
- To guarantee the functional safety in combined wired and wireless networks.
- To make wireless communication including local and wide area networks.

# 4 Conclusions and future work

In this document two Key Applications coming from the process and manufacturing industry are presented: biogas power stations and heterogeneous manufacturing cells. The aim of this document has not been to precisely describe the demonstrators, but just to sketch the work in progress.

The analysis of the different scenarios has proved that the VAN technology will have to answer to different demands (secure remote access, real-time connection between plants, easier connection between different levels of peripherals and controllers), even in the case of opposite requirements. For example, the decentralized approach needed by automation devices in order to make their reconfiguration easier and the centralized management in the power stations to provide a central supervisory, model based control, co-ordination and maintenance.

The presented use cases have following common figures (expectations) demonstrating VAN advantages over present fieldbus solutions:

- The reduction of cost measured in different aspects: work effort needed to accomplish a task, down time costs, and maintenance costs as examples.
- The increase of security in communications: the current widespreading of telecontrol solutions is limited by the fear to connect the production systems to the internet and the need for an effective protection against typical security threats (e.g. Backdoor and Trojan Horse).
- Real-time interaction among remote systems including inter-LAN communication and communication over public networks.

The bio gas power station proposed application represents a real project in progress (see table 7) and a great opportunity to track the VAN project milestones through the VAN enhancements introduced in such systems.

As a guide for future work Fig. 13 represents the interaction between the different WP´s and the Benchmarking. It can be seen that the demonstrators will verify or evaluate the indicators presented in the Benchmarking tables with the aid of the rest of the partners of the project through their specifically technical expertise. They will crosscheck the feasibility of the proposed indicators and its evaluation. The analysis of the description of the key applications could be a valuable information to use in the refinement of the requirements.

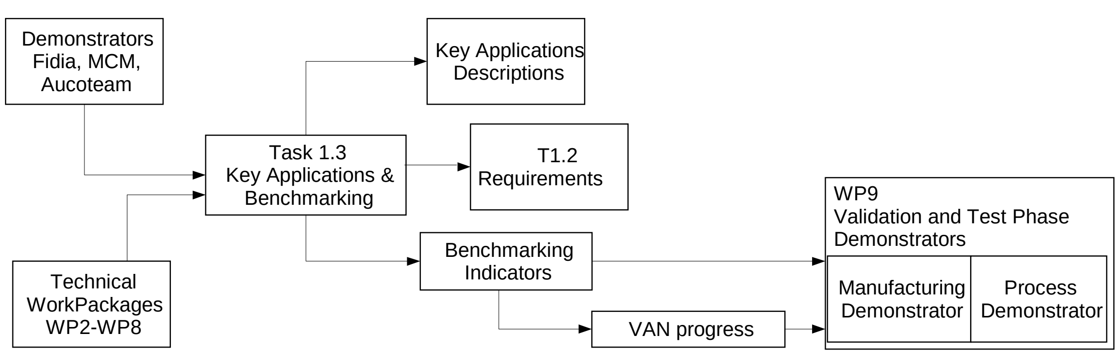


Fig. 13 Relationship with other Workpackages of the VAN project

Another main topic that is closely related to the “Demonstration” and “Dissemination” activities will be not only the achievement of the desired performance within each application, but how to convince the target audiences about the achievement obtained, above all, with regards to the security aspects, that are one of the main fears of the customers.

From an economic point of view, it can be noted the following advantages if VAN technology is included in the presented key applications:

- The inclusion of secure teleservice solutions would decrease the number of interventions of service engineers, and hence lower technical assistance feeds. The estimated economical advantage is a saving in service of about 10%, and increased sales greater than 2% due to the increased performances.
- The interoperability between different automation manufacturers would increase the sales between 3% and 10%, depending of the device (NC, servo drive, etc).
- The economic impact of reconfigurability can be roughly estimated through the cost reduction for reconfiguration activities and will be influenced by the required number of reconfigurations per year. For example, taking into account the 0% production rate for a reconfigured cell and 50% production rate for other cells every reconfiguration means a direct loss of about 14.200 €.
- The rapid grow of biogas power plants in Europe will be influenced positively by VAN based solutions due to the need for a centralised control and monitoring systems. The turnover and cash flow of these installations will be enhanced by the inclusion of the VAN strategy.

As a summary, the expectations from demonstrators (as a physical realization of key applications) of VAN project are:

- To increase security attributes of heterogeneous automation networks.
- To reach a real-time connection between the different plants.
- Easier connection between different levels of peripherals and controllers.
- Standardization of communication interfaces.