CONTROL OF THE TUNNEL-VENTILATION SYSTEM IN THE NORTHERN LINK (NORRA LÄNKEN) IN STOCKHOLM

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ABSTRACT

The Swedish Transport Administration (in Swedish, Trafikverket) needed to establish a good approach on the methodology to describe the functionality and also the demands for the operation and control of the tunnel ventilation in a new and complex road tunnel. Therefore, in the Call for Tender the technical description of the tunnel-ventilation control had to be in such a format that it could be used as a software application for the system integrator. There are some difficulties you had to be aware of in this kind of contracts. The main contractor for installations in a traffic tunnel had to handle approx. 10 different technical systems. Can we really expect the contractor to be an expert or find experts on everything, especially when this tunnel project is so particular?

1. BACKGROUND

Trafikverket makes contracts with functional requirements in major projects for installations. One major issue is to find the right technical knowledge and also at lowest cost to handle this type of tasks for a system integrator. The Norra Länken is a very complex tunnel system in Stockholm city.

Here are some basic data of Norra Länken:

- Motorway twin-bore tunnel 2x4500 m.
- The tunnel includes underground on- and off ramps
- For safety and practical reasons he tunnel is divided in 15 independent operating sections.
- The tunnel is designed for a 100 MW fire
- Longitudinal ventilation with jet fans: approx. 150 jet fans
- Jet fans with fixed speed. Some jet fans have adjustable speed and some of those are reversible
- Air-supply stations: 2 (with jet fans)
- Exhaust air stations: 3 (with jet fans)
- Dimensioned for queue and traffic congestion
- Fixed Fire Fighting System (FFFS)
- Very onerous requirements on the environmental ventilation: on internal air-quality and on minimising the impact of vitiated tunnel air to the environment at the portal zones
- DCS, Control system (ABB 800Xa) with approx. 11300 objects.
Layout of the Ventilation system and Sensors

![Diagram of the tunnel-ventilation system showing fans and sensors.]

**Figure 1:** Norra Länken layout of the tunnel-ventilation system showing fans and sensors.

We have to bare in mind that neither the contractors nor the Client has got extensive experience in complicated solutions for tunnel-ventilation. Moreover, the contractor can’t be expected to make all simulations and make the strategic thinking for fire-ventilation and environmental-ventilation. This is the responsibility of the Client, Trafikverket.

2. **WORK PROCESS**

Our task was to produce documentation so good that it could be used as basic data for software application for the system integrator.

There are different approaches of documentation to accomplish that.

- Text description for all jet fans and sensors
- Excel documents showing all jet fans and sensors
- Graphical function drawings
- Graphical layout of the tunnel-systems with all information included for fans, air velocity, etc. Combined with a text document describing type object and demands.

**Text description**

This is the most common way to describe different technical systems and objects in process applications.

The document normally requires a description of each object for its alarms, interlocking, parameters and normal operation for one type object or a complete system.

So if you should use it as a document for a software programmer for a control system, it had to be very detailed and correct in its descriptions.
Matrix layout with Excel

This kind of documents shows all fans in different locations and how they should operate in different operating modes.

As for the Text Description, a text document is still required for a more detailed description of each object for its alarms, interlocking, parameters and normal operation.

Also in this case, if you should use it as a document for a software programmer for a control system, it has to be a very detailed and with correct descriptions.

Graphical Function drawings

(Power-plant documentation according to VGB-standard. VGB is the European technical association for power and heat generation)

This is a very detailed documentation and it describes how the software for the control system should be done. It always starts with an overview. Here the function is described with graphics function blocks in an overview style (Figure 2).

![Figure 2: Example of an overview with graphics function blocks according to VGB-standard.](image)

Then in the next example, it is described in a more detailed style (Figure 3). This is a drawing with graphics function blocks. Here, a software-programmer has all the information available to make a software application for this object. As you can see, it tells you that this controller is in a process picture with graphic display and alarms. It also shows that it has hardware in the desk for parameters as set-point and it shows the actual value there. Then it shows all graphic elements for this function. All texts are already there and even the hardware position in the cubicle and the name of the software program. In this case, you don’t have to be an expert programmer to realise this function. In the working process, the programmer selects the graphic functions blocks from a software library and connects them to make a software application. In order to produce this kind of document, it takes a lot of skill and even then, you have to be an expert on your technical system.
3. ALTERNATIVE APPROACH

1. Because of the functional demand structure in our contract, there were some basic rules we wanted to impose. Provide functional demands and let the contractor make the construction and have the responsibility.

2. Provide a technical description for the tunnel ventilation-system with its alarms, interlocking, parameters and normal operation.

3. Provide a graphical layout of the tunnel-systems with all information included for all fire cases and for ventilation (in-tunnel air quality).

Trafikverket selected the Graphical Layout of the tunnel-systems made in Excel. The document called the governance principles for smoke ventilation. The reason for this was to make it so good that it could be used as basic data for software applications and it can also be used in the testing phase for an easy verification of the control strategy. It shows in this overview format all fans and air-ventilation stations. It gives information on how the tunnel is divided into different ventilation areas and the names of the different tunnels. Each drawing shows a fire scenario in a specific location and how the control system shall control each jet fan. All values are made from simulations runs. There are also text describing general rules and principles. For the reader, the colour marking helps understanding what happens under different scenarios. Different modes of operation for the jet fans are clearly indicated.
The Graphical Layout of the tunnel system consists of two parts: one is for the fire-ventilation that has three different ventilation modes (also known as strategies).

- Minimal Fire-ventilation with an air velocity of approx. 1-2 m/s
- Fire-ventilation with an air velocity of approx. 2-3 m/s
- Forced Fire-ventilation i.e. maximum possible air velocity

This is a static control of jet fans but some connected ramps have an active control of jet fans with frequency converters for ensuring a certain flow maintaining a back pressure.

This documentation contains approx. 120 such layouts.

Figure 4: Example of the control principles for Fire ventilation

The second part consists of the environmental ventilation and the different control chains. During normal operation, the environmental ventilation has two objectives:

- Internal environmental ventilation (in-tunnel air quality)
- External environmental ventilation (impact on ambient air quality)

It has the same basic layout as for the fire ventilation and describes the different ventilation areas depending on which control chain is in operation. This is an active control of jet fans and air- supply and exhaust-stations.

The documentation for this contains approx. 30 such layouts.
Text description

The main text description consists of a document that describes the ventilation strategy with different operation modes; Minimal fire-ventilation, Fire-ventilation and Forced fire-ventilation. It also describes monitoring of jet fans i.e. running time, start counter, safety functions, interlocking and fan redundancy.

The next part describes the environmental ventilation and the different control chains, for Internal environmental ventilation (in-tunnel air quality) and External environmental ventilation (impact on ambient air quality).

4. SECOND OPINION

Trafikverket wanted an external review, so we contacted Dr Rune Brandt from HBI Haerter in Switzerland to scrutinize all documentation. Dr Rune Brandt gave us some valuable recommendations and we made changes mainly in the layout of environmental ventilation. Subsequently, all documentation was included in the contract for installations in Norra Länken in 2010.

The Norra Länken project will start commissioning during 2014 according to those documents.