3D Data Fusion for 3D Modeling Applications for The Energy Sector

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Key words: Laser scanning, 3D modelling, BIM, 3D, Facility Management,Cadastre

SUMMARY

The energy sector is a business area that has a lot to benefit from 3D data acquisition and modelling technologies. 3D Terrestrial laser scanning, Multibeam, ROV, UAV 3D and imagery data acquisition are all means of obtaining data in the form of point clouds. 3D data fusion from various sources can be processed into models and streamlined into engineering projects that may involve: 3D visualization, 3D dimension and position querying, creation and publication of annotations, modelling of existing terrain and infrastructures especially in remote unmapped areas, As-Built-BIM, integrated MEP documentation and modelling, inspection and documentation of existing structures, projects of rehabilitation for old power plants, factories, dams, industrial facilities, facility management, deformation analysis and monitoring, finite element analysis, CFD, volumetric surveys, stress-strain analysis etc.

Several case studies are discussed based on the author's long and extensive experience in 3D data acquisition and processing into suitable outputs like 3D CAD models, BIM models and a wide range of custom designed products. Moreover, the authors present the challenges that come with the data acquisition and integration of these processes into various workflows and they describe how in cooperation with their clients they deliver high quality results, by building on their skill and utilizing multidisciplinary approaches.

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1. INTRODUCTION

Over the past years, huge investments have been made in all kinds of facilities, power plants, processing units and infrastructure. Looking at the energy sector today it is obvious that a significant amount of work is required to address issues of aging structures and of structures that need to be upgraded or modified in order to meet environmental requirements and new standards of operation for health and safety. In addition to the above, the constant need to produce and distribute new, cleaner and sustainable forms of energy, shape a business area of huge potential. In this context, surveying engineers are in a position to make a significant contribution in order to assist all other engineering disciplines on all kinds of projects that are underway in the energy sector.

2. PROJECT REQUIREMENTS IN DATA ACQUISITION AND MODELLING

It is beyond doubt that the energy sector is one of the most interesting business areas for surveying engineers who deal with 3D data acquisition and modelling. Projects of all kinds and sizes require constant support with all types of data and models, thus a significant rise in demand for this kind of service is noted. Work in the energy sector, may involve new design, rehabilitation of existing structures and in a few cases scope of application may be facility management.

For a few cases, interest is focused on a limited area, like part of a building or an installation. However, most projects involve the documentation and modelling of large, complicated structures and their surroundings. In energy, most structures usually extend over large areas, with installations that cover a space that may well be in the order of a few square km, including buildings, structures, installations, systems, assets, mechanical equipment, electrical components, tunnels, canals, power lines, pipelines, dams, processing units, plants, storage spaces, docks, roads, bridges, towers, large factories etc.

For projects in the energy sector, all decisions involving any kind of construction or modification are made not only based on safety codes, design constrains and requirements, but also on studies regarding to how the physical and visual environment is affected. In this respect, there is always a need for support with various data and models even during very early stages like feasibility studies.

Once projects are underway, work on either new construction or rehabilitation requires constant feed and support with data and models from site to facilitate engineering work of all kinds. For projects involving new construction, surveying engineers are involved in implementing design out in the field, quantity surveying and monitoring of the construction process. Of course, construction is hardly ever a linear process, especially for projects that extend over large areas and involve massive operations. Challenges that could surface during the construction phase may require changes and updates in design. In this case, surveying engineers have a truly key role in connecting the construction field and the design office. For projects involving rehabilitation of aging facilities and units, surveying engineers are involved from the very early stages documenting existing structures and systems. Depending on the type and scope of every project, the nature of 3D documentation process may vary significantly. This kind of projects is perhaps the most interesting one as complete documentation of existing structures may require the use of the entire range of data acquisition services such as Terrestrial laser scanners, total stations, GPS, drones for airborne laser scanner data and images, underwater scanner data, data from ROV etc. In some cases, major projects that affect larger areas may require use of terrain and imagery data from national data services. In addition, when project areas are inhibited, it can also be necessary to acquire and integrate GIS data in the models that document the existing situation.

While selection of the suitable data acquisition technologies might be straightforward, the modeling process still presents several challenges. The requirement for use of BIM for most of the projects that are currently underway often pushes the boundaries in the area of 3D modeling. In order to support various stages of BIM production it may well be necessary to build several kinds of models such as polygonal, NURBS or TIN surfaces, watertight models, solid models etc. Also, in order to accommodate needs in modelling for all kinds of disciplines combined in BIM, several factors come into play, such as the use of global and local coordinate systems, interoperability of formats, sizes of data sets, combination of data and models from various sources, model size restrictions etc. In the same context, and in order to assist all project stakeholders towards collaboration, integration and communication, models may need to be transformed or adjusted according to the requirements of systems and software in use.

In terms of standards, there is a rather long way ahead. Efforts for establishment of International Construction Measurement Standards [1], are underway, but no guidelines are yet available. Similar is the status in the International Property Measurement Standards [2], where the IPMS for Industrial Buildings is still not available. In the absence of standards, desired accuracies for work carried out on site for all kinds of projects are determined by project requirements related to construction and rehabilitation processes. Also, in cases where BIM modeling is employed for creation of As-built-models, BIM manuals such as the those published by Stattsbygg [3] (Main building authority in Norway), may serve as an alternative way to specify desired accuracies on projects.

In the next section, the authors present selected projects where data of different sources were combined into models in order to assist further engineering work.

3. SELECTED CASE STUDIES

3.1 New Construction design

Subject of the project presented in this section is a new hydropower plant currently under construction on the outskirts of Oslo. The new unit will be one of the biggest of its kind in Norway.

The project is entirely and directly designed in 3D as a BIM model and it is the first project to be handled as a completely paperless project. Structures, infrastructure and assets cover an area of approximately 1 square km. Data capture during initial stages included airborne laser scanner and image data sets along with mapping and GIS data for the area acquired from national level databases. In addition, with the aim to create a more complete 3D documentation of existing structures terrestrial laser scanner data sets and close range images were acquired. The system used for airborne laser scanner data capture was a Riegl VUX-I on a helicopter platform which included the MicroIRS IMU, a Topcon Legacy E GPS and a Nikon 810 Camera. Terrestrial Laser scanner data was acquired with a Leica C10 and several control points have been surveyed on site using GPS and Total station. All captured data are delivered in the NTM-11 reference system, which is used in Norway for all new constructions. Combining the aerial images and the laser scanner data, orthophotos of 2cm pixel were delivered for the project. Airborne laser scanner data, acquired at a density of 50 pts/sq m were classified into categories and delivered in LAS format. Terrestrial laser scanner data were also delivered in LAS format. Both data sets were combined for visualization and use in modelling software (FIGURE 1).

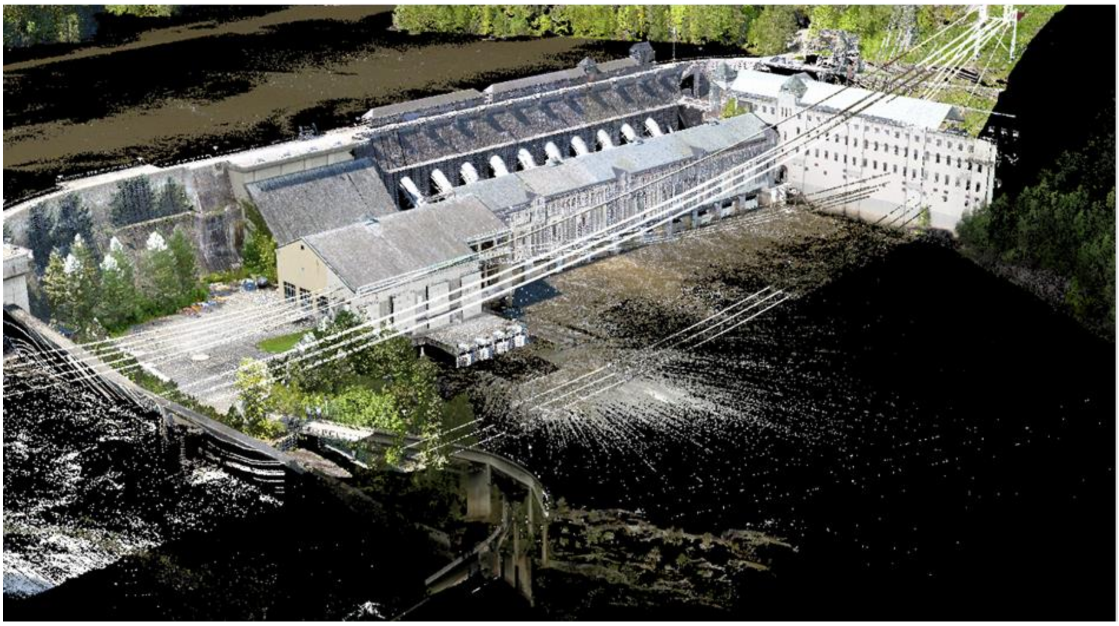

FIGURE 1: Combined aerial and terrestrial laser skanner data sets

Modeling of infrastructure, and various structures found in the area were modelled as NURBS surfaces and solids in Rhino. Rhino, was also used on more modelling production processing stages in order to integrate models from different sources, perform boolean operations, trace cables, create contours etc (FIGURE 2).

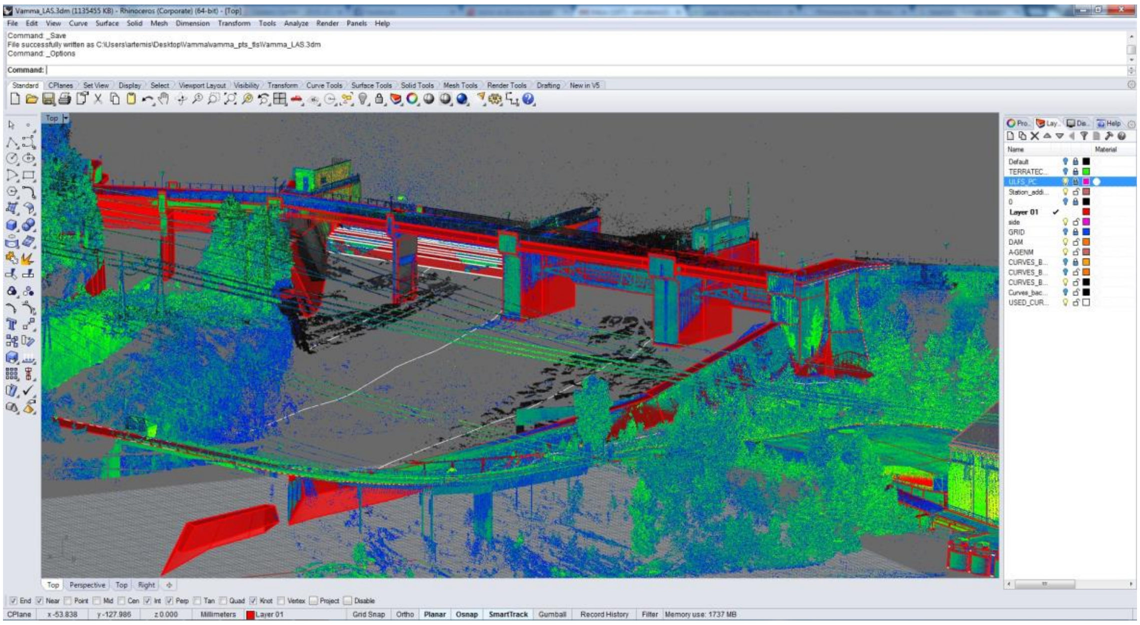

FIGURE 2: 3D modelling of structures after point cloud data in Rhino software

Buildings and some more structures that are found in the area were modelled using Revit again based on pointclouds. In terms of terrain modelling, Revit does not support models of large sizes. Therefore, it is preferable to insert a decimated pointcloud of ground surface data and allow the software to calculate an element like a toposurface, which can then be used for the rest of the modelling process in a regular REVIT workflow (FIGURE 3).

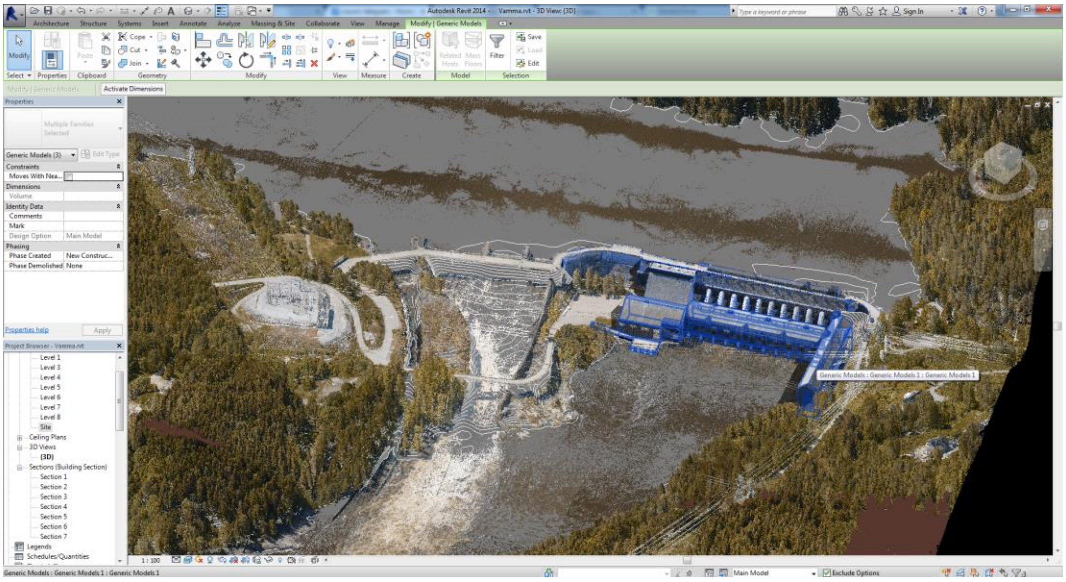

FIGURE 3: 3D modells of existing structures, 3D toposurface and pointclouds in REVIT

Combining terrestrial and airborne laser scanner data, a polygonal surface terrain model was created using Geomagic sw. Using Agisoft, the terrain model was combined with the original images into a textured terrain model in OBJ format. The result could then be imported in 3DS Max and further processed for creation of renderings and virtual environments.

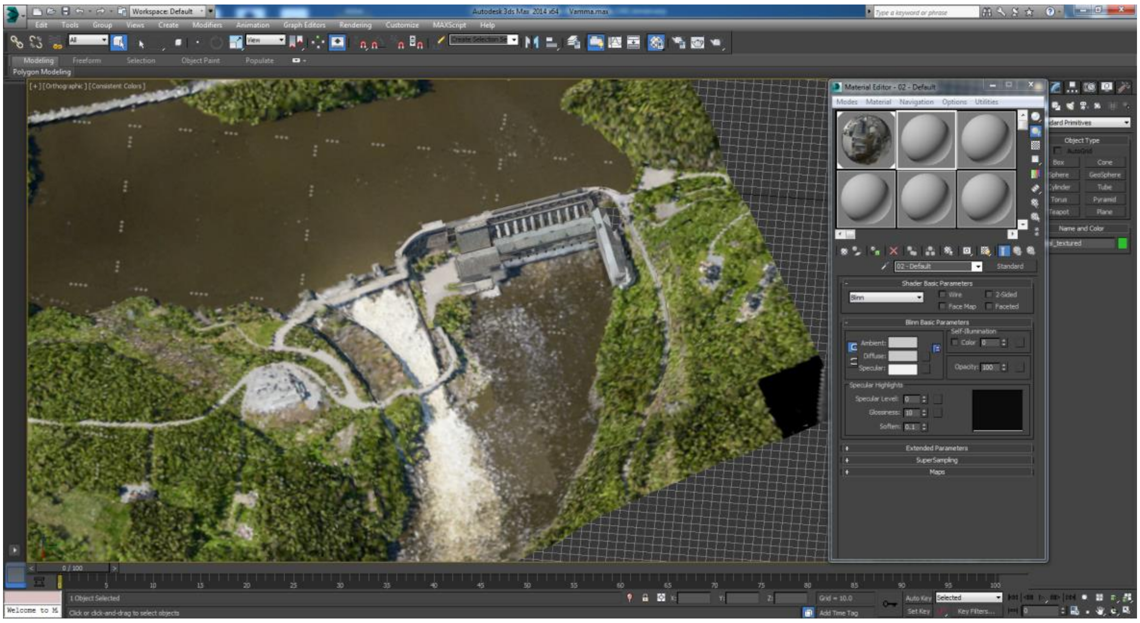

FIGURE 4: Textured 3D models of terrain and existing structures in 3D Studio max

All models created using the point clouds data have been imported and utilized in all kinds of software, including software used for BIM coordination and delivery. Autodesk NAVISOWORKS is the main software used in this project for coordination, collision check, running audits and for delivering information about objects that are being built, including materials, bill of quantities etc (Figure 5). Finally, using services like Autocad A360 there is the possibility to visualize delivered models on site using portable devices such as tablets (Figure 6).

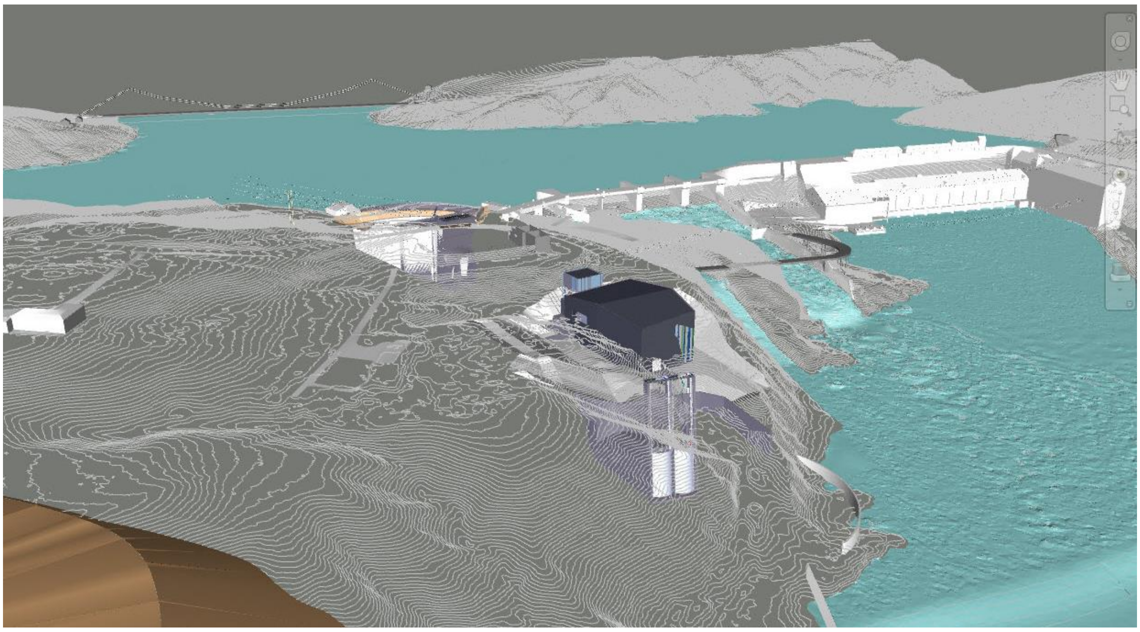

FIGURE 5: Snapshot of BIM model in NAVISWORKS

FIGURE 6: Snapshot of BIM model in NAVISWORKS

3.2 A rehabilitation project

One more case that is interesting to discuss in this context is a mission undertaken to support work on a hydropower plant rehabilitation project. This hydropower plant is part of a group of units along a river in Sweden, where several projects are underway to upgrade total power production. In this case, a small hydropower station has been scanned using terrestrial laser scanners systems as well as an ROV system, which offers the possibility to scan a waterway without the need to stop and redirect flow, a process that usually involves a significant amout of work, coordination and a considerable cost. During an initial mission the old hydropower plant was documented using a terrestrial laser scanner, an external camera and the waterway was captured using an ROV system (Figure 7).

ROV data captured on site have been combined into 3D CAD solid models. In areas of steady flow, the data captured allowed for the precise modeling of those areas, something that was initially confirmed by comparing the solids produced with existing as built drawings (Figure 8). However, unusual and non steady conditions of flow inside certain areas inside the waterways rendered the some of the acquired data too unreliable for modelling. Therefore, in an effort to create a complete representation of the shape of the waterways existing drawings were used to support the modelling process in the areas where the ROV data capture had failed (Figure 9).

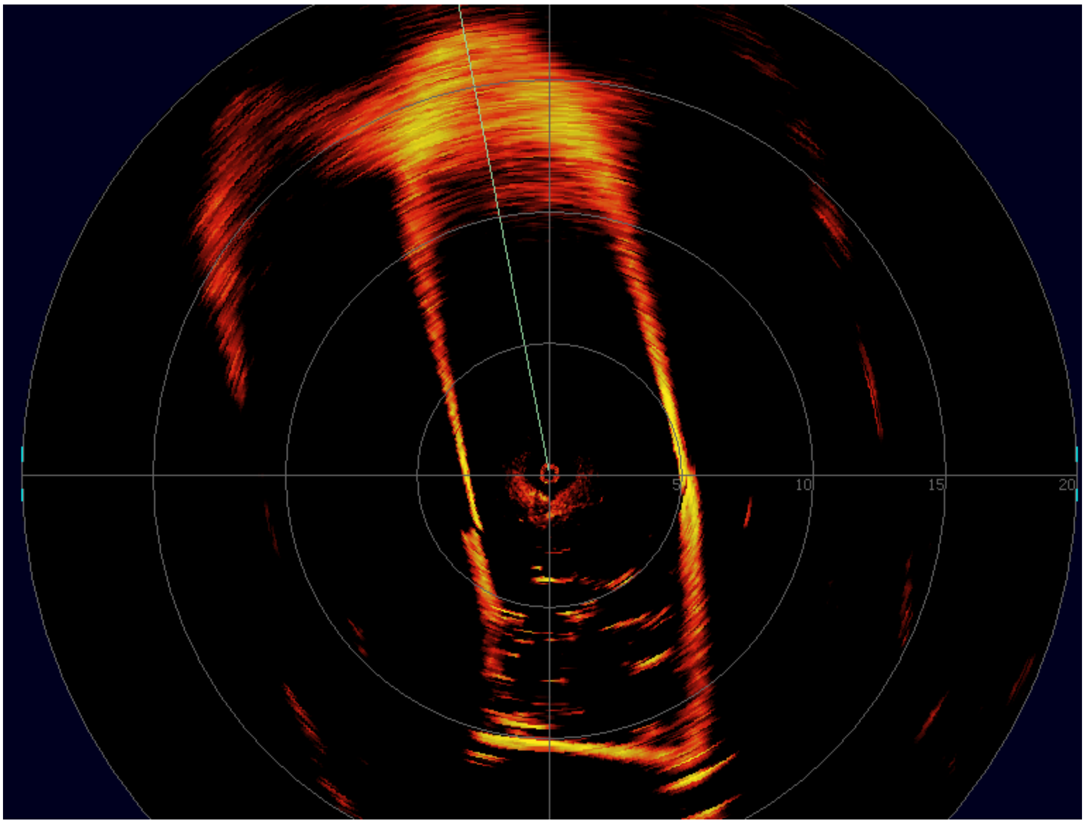

FIGURE 7: ROV data snapshot

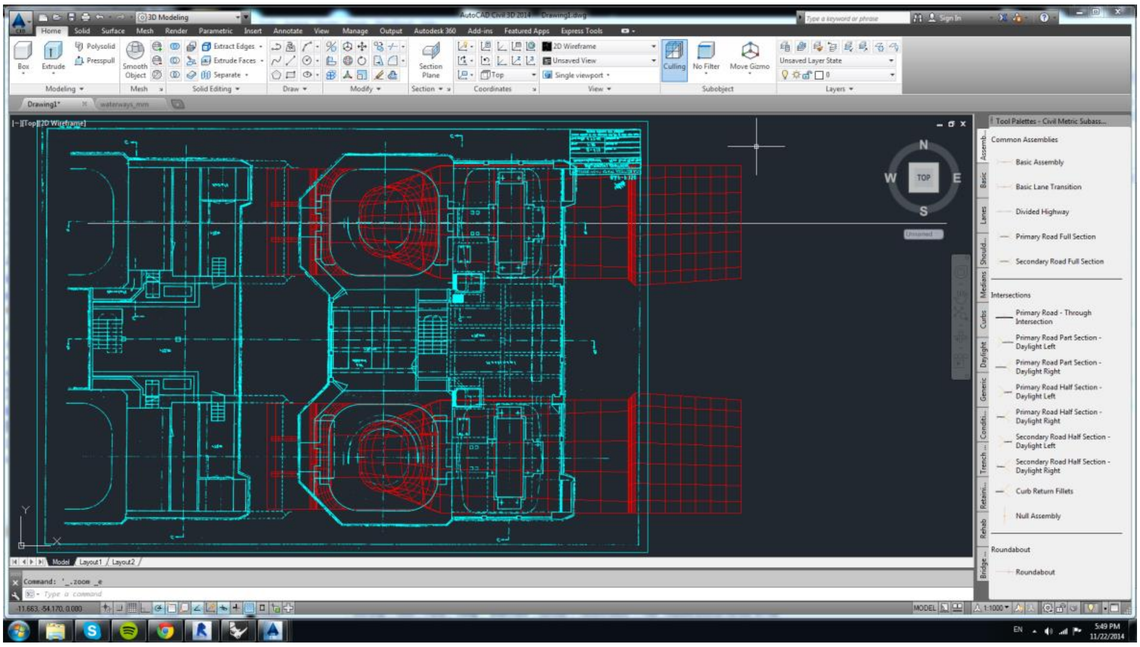

FIGURE 8: Comparison of 3D models created based on ROV data compared to blueprints

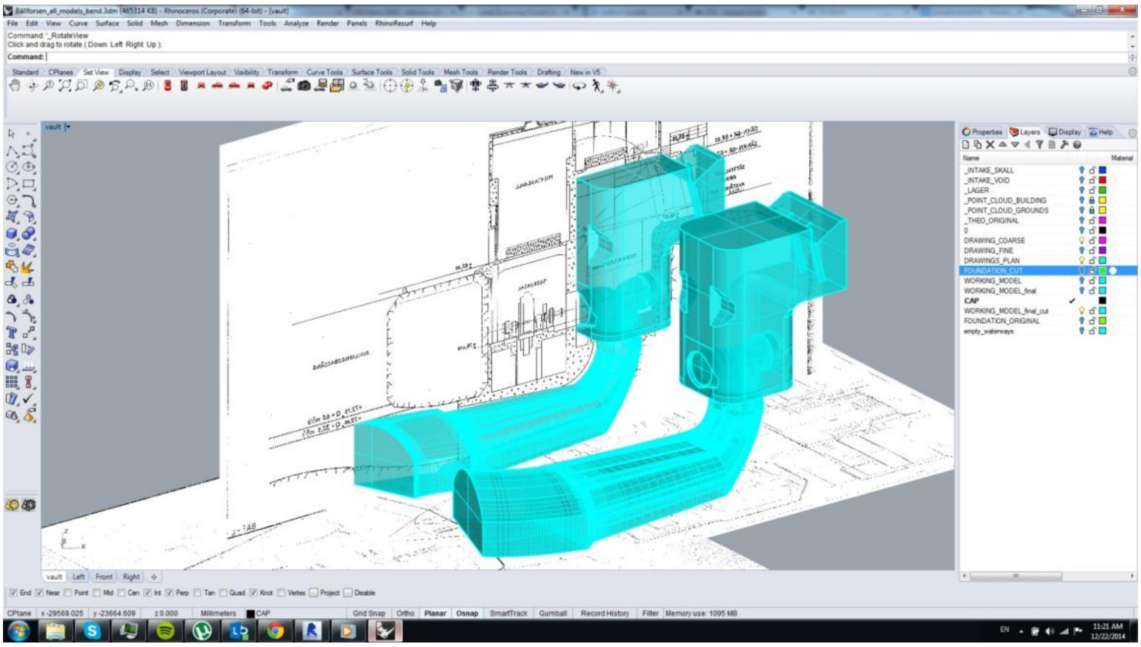

FIGURE 9: Modelling of 3D waterway models based on ROV, laser scanner data and blueprints

TLS scans were also obtained on both the exterior and the interior of the power plant. The data, combined and exported in pts format were imported in REVIT where all building elements were modeled in a BIM model (Figure 10).

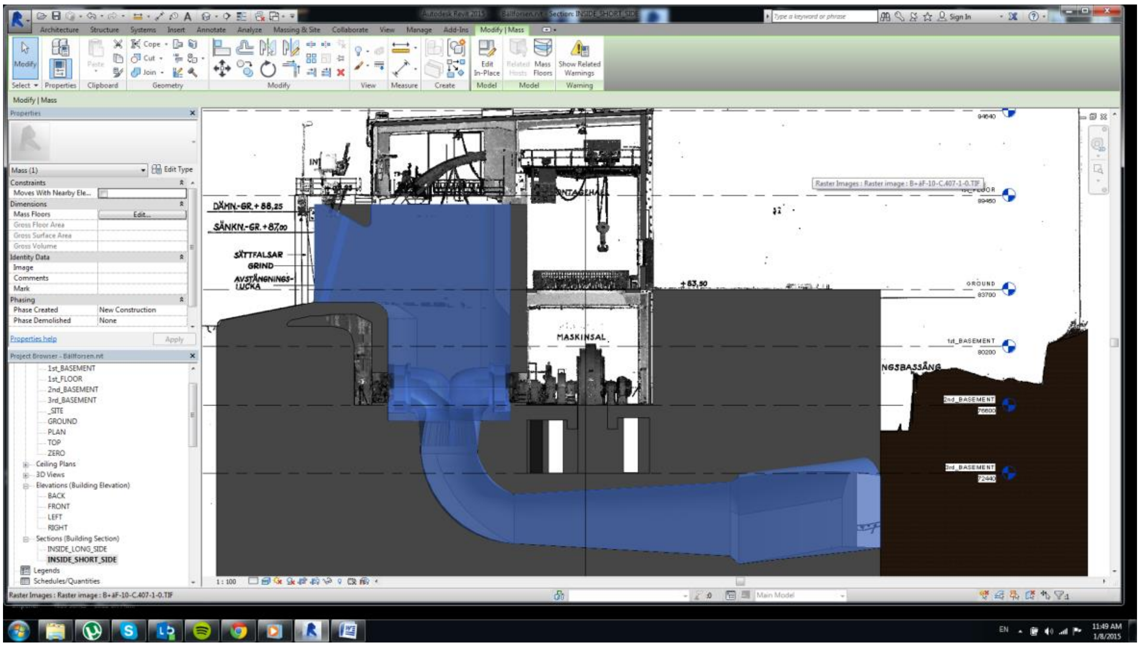

FIGURE 10: BIM model of hydropower plant developed for rehabilitation project

However, knowing that data capture had failed in some areas due to turbulance, and in light of the decision that the mechanical system of the turbine should be replaced inside the waterways, a new mission was decided, the first waterway was dried completely and the shape of the entire waterway was captured with a terrestrial laser scanner. The new model replaced the old one in the BIM environment. (Figure 11). This entire process, allowed the authors to compare the results of the ROV process with those of the laser scanning 3D data capture. Of course, TLS gives higher accuracy, but it was also found that in areas where conditions were favourable, the ROV model was also accurate, and this is something to consider because the process of draining a waterway is a heavy and costly task.

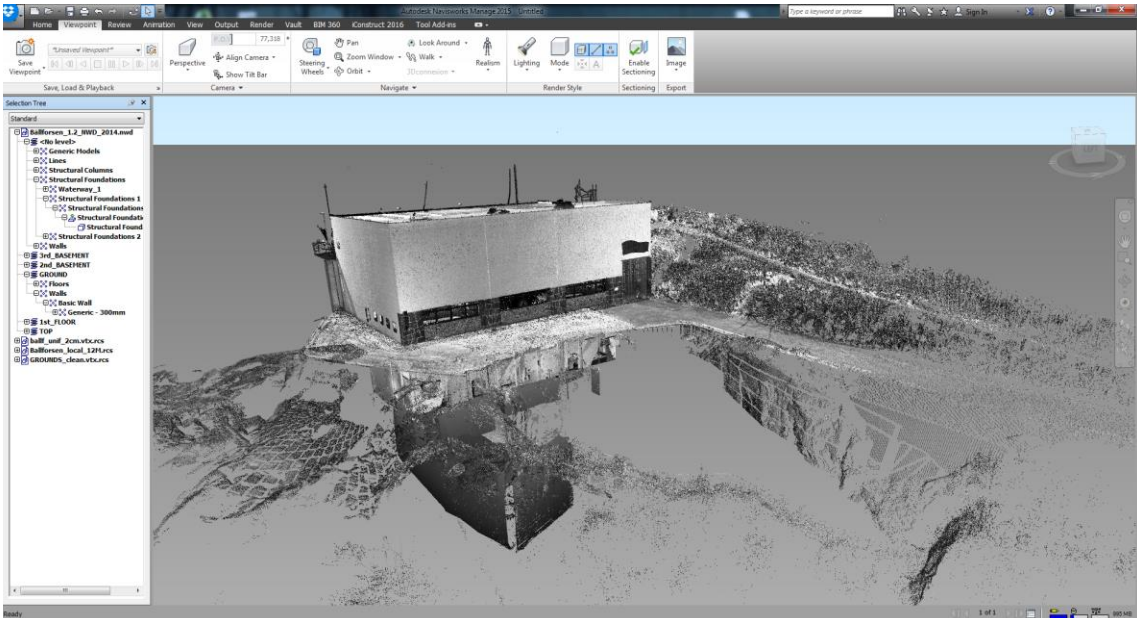

FIGURE 11: Hydropower plant BIM model and laser scanner data in NAVISWORKS

3.3 A 3D documentation project

The project presented here, is part of a bigger project that is underway currently and involves the documentation, rehabilitation and upgrade of several power stations and the included distribution power lines. For this project, all kinds of data are being combined for documentation, mapping, visualization and modelling to support engineering work. In order to map existing power lines, DEM data, orthophotos and GIS data are obtained and processed into software like AutoCAD, Revit and Infraworks, in order to assist decision makers in new design and new routes for power distribution networks. Also, for some parts of the project, terrestrial laser scanning is being used to document existing structures and assets. In this case, an entire electric substation has been captured using a Leica C10 (Figure 10). Working with a scanner in an area like this requires special safety measures while on site. Also, due to high voltage, there is some noise in the captured data.

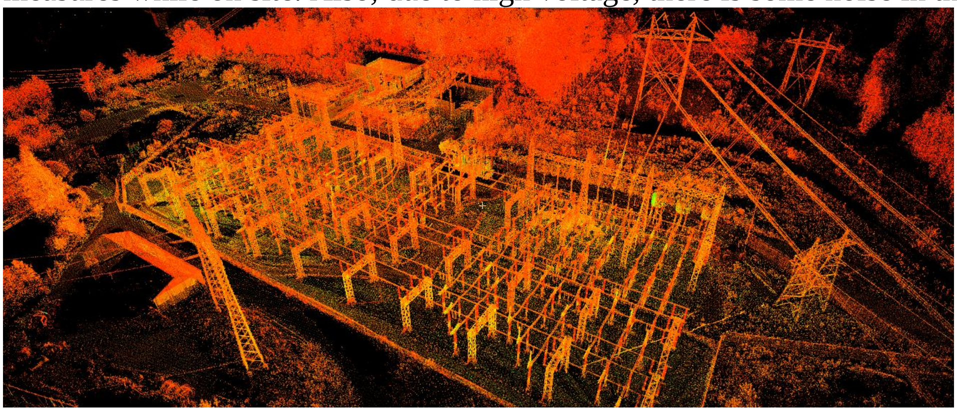

FIGURE 10: Snapshot of Point CLOUD data for an electric substation

In order to support engineering work, the data captured was modelled into a Revit model. The original pointcloud was segmented in parts that were then imported into Rhino 3D modelling software. Usinde the pointclouds, equipment components inside the grid were modeled into solid objects. These objects, were aftewrads imported into Revit and object families were created for each type of the modeled compontnets. Once object families are created, it is easy to populate the entire grid space with copies of these objects placed accurately onto the laser scanner data. All objects are first placed on a horizontal view and then section views are used to adjust the position of all of these components vertically. Creating a grid of section views for a project like this, is very useful not only for accurate placement of equipment componenents, but also for their visualization and presentation in drawings (Figure 11). The drawings produced in this way can be used for further engineering work for this kind of projects.

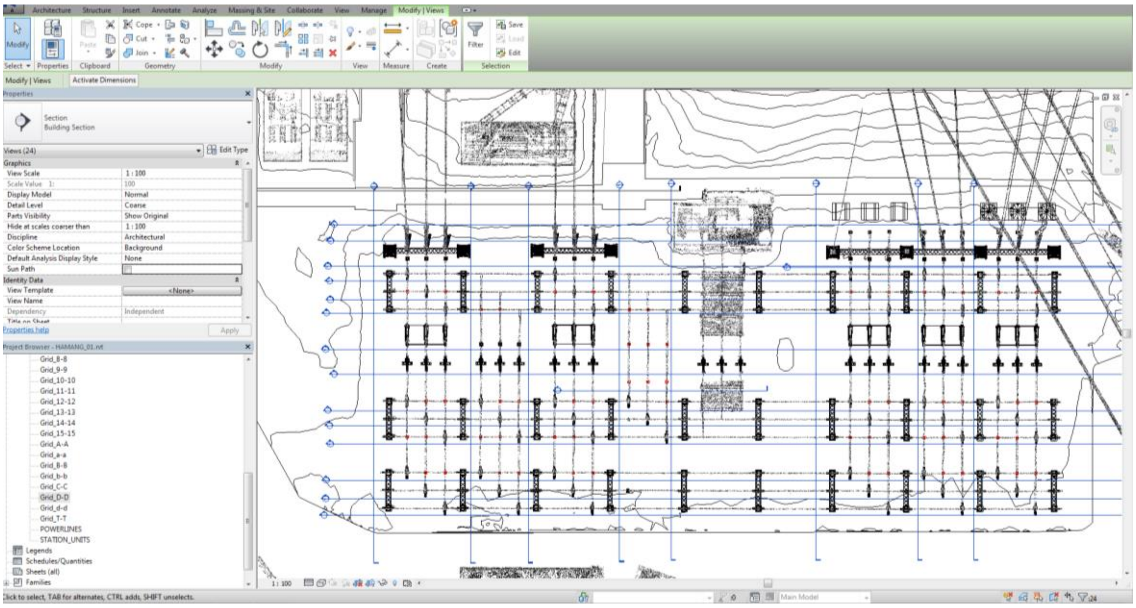

FIGURE 11: Electric substation model in REVIT

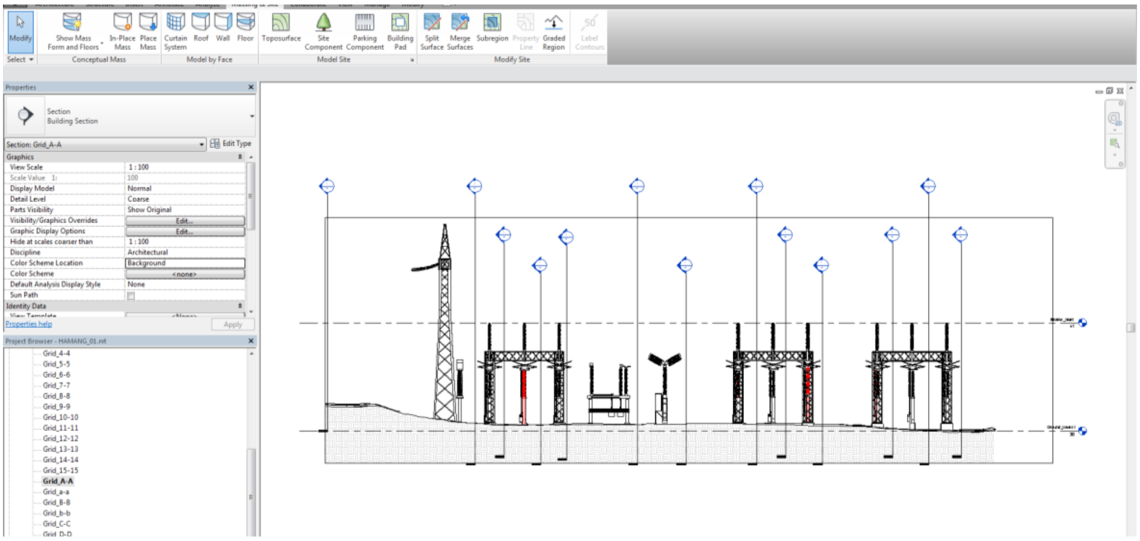

FIGURE 12: Cross Section view of electric substation model in REVIT

4. CONCLUSIONS

The energy sector is definitely one of the most exciting areas for any surveying engineer who works with 3D data acquisition and modelling. The wide range of applications in this area give the opportunity for employment of all kinds of data capture and modeling methods. Moreover, the requirement for modeling in some kind of BIM environment and the need to enable utilization of 3D input for all engineering disciplines shapes a very interesting and challenging work area. In this respect, the role of the surveyor is key to provide all kinds of projects with suitable, high quality data, assist other engineers in designing new workflows for data fusion and integration into models. Surveying engineers are in a position to ensure that all projects underway are documented in a way that will facilitate ongoing work and accommodate future needs during the entire life cycle of a structure or an installation.

REFERENCES

International Construction Measurement Standards (ICMS) Dec 2015, http://www.ciqs.org/_literature_185820/International_Construction_Measurement_Standards_(ICMS)_Dec_2015

International property Measurement Standards, http://ipmsc.org/

Stattsbygg BIM Manual, http://www.statsbygg.no/Files/publikasjoner/manualer/StatsbyggBIM-manual-Ver1-2-1-2013-12-17.pdf

BIOGRAPHICAL NOTES

Anders Nesse graduated as master in photogrammetry and surveying at the Agricultural University, Agricultural University, in 1990. During his career, Nesse had responsibilities related to the sale and implementation of geographic information systems, CAD systems and digital photogrammetry. Between 2002-2006 he has also been involved in the sales and support of management solutions for buildings and parks. Today he works as GIS and local government consultant at Norconsult Information Systems, NOIS AS.

Ulf Hägnefelt is responsible for laser scanning services and business development at Norconsult AB. He works as a project leader and coordinator on 3D laser scanning operations supervising all stages from mission design to finished models and drawings. Clients include government agencies, such as the National Property Board of Sweden (SFV), as well as municipalities, municipal departments, contractors, real estate companies, architectural firms and others.

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