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CONTRACT NO: COOP-CT-2005-513137

TRANSMAN

A Product to Extend the Life of Energy Transmission
and Distribution Transformers by Total Management of Insulation Systems

Co-operative Research (Craft)
Horizontal Research Activities Involving SMEs

Final Activity Report

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ABSTRACT

A Consortium of European SMEs has completed a successful FP6 Cooperative Research project to develop monitoring and treatment systems to extend the life of and improve the reliability of existing high voltage transformer networks. The Project has addressed the problems associated with the contamination of transformer insulation by successfully developing oil filtration and monitoring systems.

The TRANSMAN system can successfully treat and condition contaminated transformer oil by removing both particulate matter and moisture, while also offering a monitoring solution for particle content.

The SMEs and Researchers have created a system that has the potential to will improve transformer reliability and thus boost the integrity of the power distribution networks throughout Europe.

OVERVIEW

High voltage power transformers have a life of approximately 40 years. The majority of transformers in the power distribution network in Europe were installed in the 1960s and 70s and these transformers are now reaching the end of their life. There is a need to extend the life and improve the reliability of existing high voltage transformer networks thereby satisfying the European directive for ensuring the security of power supply, the desire for power utilities to maximise the financial return on their assets and improving the quality of life for society.

The TRANSMAN project has enabled a European Consortium of small to medium sized (SME) companies and Research Performers to successfully complete a two year European Research project to develop an innovative product to manage, monitor and treat transformer insulation - the most influential factor in extending the life of transformers.

1 PROJECT EXECUTION

Project objectives

The objective of the TRANSMAN project was to produce viable prototype device that integrates key technology elements of power transformer oil insulation monitoring and treatment into an automated process system.

Moisture is the most dominating influence on the insulating characteristics of the transformer and the TRANSMAN project has succeeded in the development of dehydrating and particle removal technologies that operate on line with minimal or manual intervention. The technology has the ability to remove moisture down to levels of approximately 10-20 ppm of water in the transformer oil, and can remove particles from the oil $<2\mu\text{m}$ dependent upon the filtration elements used within the system. The TRANSMAN system is also capable of monitoring the particle removal process by incorporating an optical particle count/size system.

Much of the existing technology available to manage transformer maintenance only addresses individual aspects of transformer performance such as gas analysis or dehydration in isolation. From the point of view of dehydration the current techniques are imperfect due to the need in adsorbent systems for regular checking and changing of filters.

Specifically, the key scientific and economic achievements of the TRANSMAN project are;

- The real-time measurement of particles of micron-scale dimensions within transformer insulating oils
- The development of a moisture removal and conditioning system for on-line processing of transformer insulating oils
- The development of an on-line filtration system for the removal of micron-scale particles from transformer insulating oils
- The creation of intelligent transformer management software for the effective monitoring of transformer condition

Contractors

Lead Contractor:	Kelman Ltd, Lissue Industrial Estate, Lissue Road, Lisburn, BT28 2SA, Northern Ireland
SME Contractors:	Electricidad Industrial Salvio Busquets SA, Almogavers 215, E-08018, Barcelona
	GRAS Sound and Vibration Aps, Skovlytoften 33, DK-2840 Holte, Denmark
	Optilan Ltd, 8 Jury Street, Warwick, CV34 4EW, UK
	Pantreon GmbH, Kirchengasse 4, A-4810 Gmunden, Austria
Other Contractors:	ESB International Group Ltd, Stephen Court, 18/21 St Stephens Green, Dublin, Ireland
	Instytut Energetyki, Mory 8, Warszawa, 01-330, Poland
	Semelab Plc, Coventry Road, Lutterworth, Leicestershire, LE17 4JB, UK
RTD Performers:	Pera Innovation Ltd, Nottingham Road, Melton Mowbray, Leicestershire, LE13 0PB, UK
	Fraunhofer Institut Umwelt, Sicherheits, Energietechnik, Hansastraße 27, 80686, München, Germany

Approach

To achieve the objects of the TRANSMAN project an ambitious programme of research and development was undertaken under the FP6 Cooperative Research scheme by the consortium in order to overcome the projects technical goals.

The scientific research work was required in order to;

- Develop of drying technology efficient enough to meet the requirements for removing oxygen and moisture in a compact system which does not require ground works to install
- Improve understanding of dehydration technologies related to the increased ability of oil to give up the water dissolved within it
- Develop optical diagnostic and monitoring technologies to determine the condition of the insulating oil
- Adapt of membrane technologies for incorporation within oil conditioning systems.

- Develop intelligent transformer management software for the effective monitoring of transformer condition.

The Cooperative Research instrument offered the SME partners access for the first time the world class research expertise of two European Research Teams in Oberhausen, Germany, and in Leicestershire, UK. Together with the industrial drive, economic and market driven focus that the SMEs provided the collaborative research team followed the planned project approach and has achieved all of the projects goals and objectives.

Results

The SME and Researchers have created a management, monitoring and conditioning system for transformer insulating oils that is effective in monitoring and removing contaminants from transformer oils.

A number of developments have been made possible as a direct result of the TRANSMAN project;

Real-time particle sensor

The development of a system to provide quantitative analysis of the size distribution and population of particulate matter within transformer oil was undertaken in order to provide diagnostic information regarding the state of the oil with respect to this particulate matter. Existing particle measurement systems are either prohibitively expensive (tens of k€s) or offer only an estimation of the particle count. A system was developed incorporating a waveguiding approach to illuminating the oil sample, minimising background illumination and maximising contrast resultant from light scattered by particles. Low cost optical elements were assembled into a portable prototype device for on-line particle monitoring to be used in conjunction with the oil conditioning system.

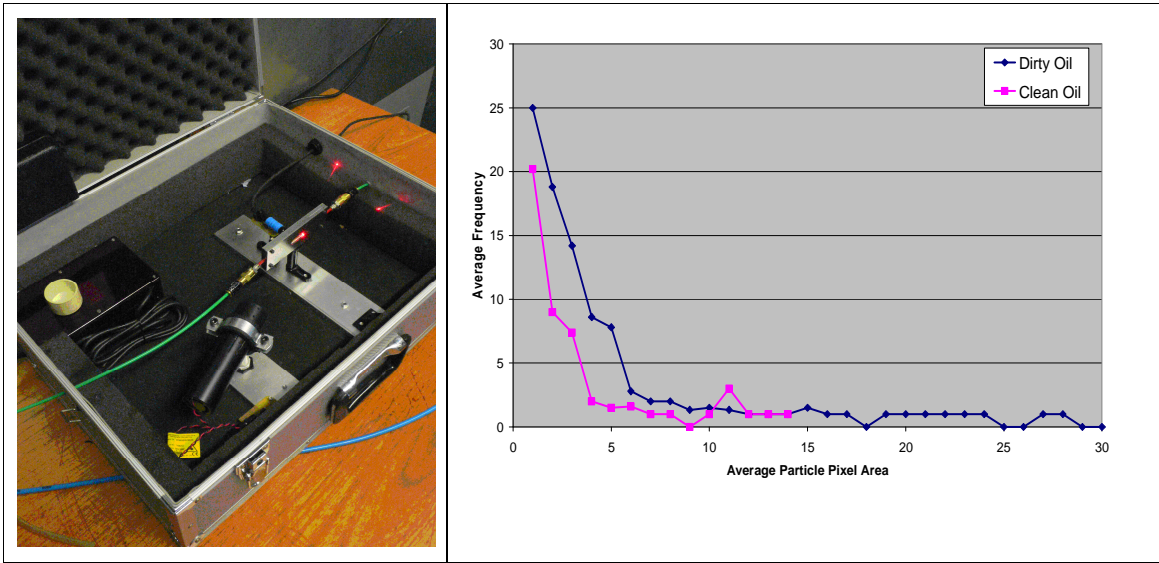


Figure 1. Particle sensor and particle report

On-line particle filtration system

The particle filtration system comprises porous membranes the rotation of which causes turbulent cross flow on the membrane surface and thus avoids particle deposition and blocking of the pores much longer than in normal cross flow filtration units.

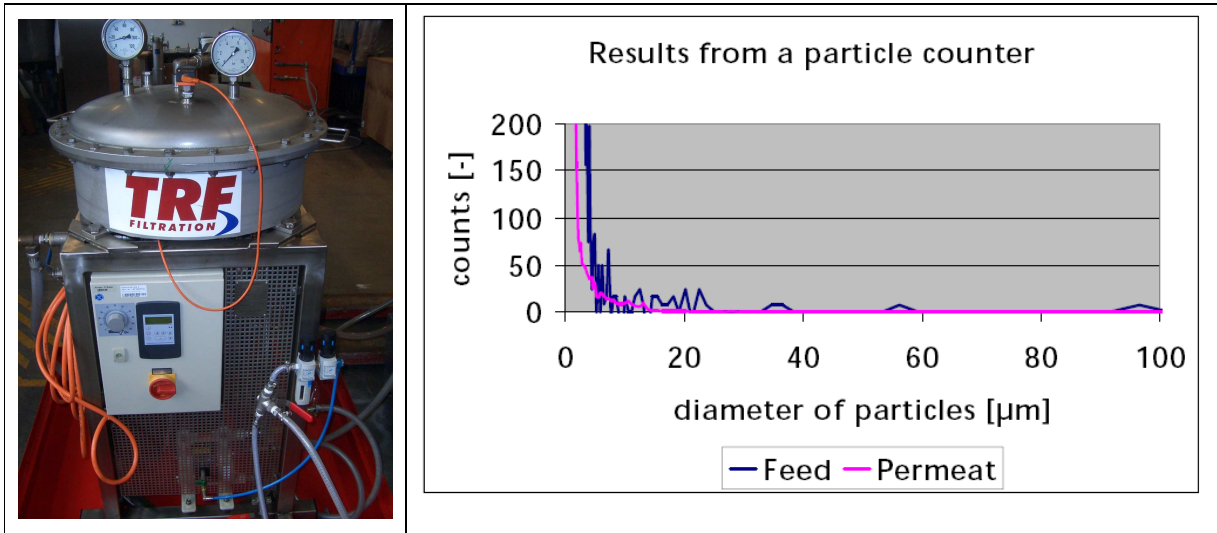


Figure 2. Particle filtration unit and filtration performance

On-line moisture removal system

The on-line moisture removal system is compact and consists of recyclable packing material that can be regenerated by the application of heat, rather than the industry standard Fullers earth, that must be disposed of as chemical waste.



Figure 3. Moisture removal unit with conditioned (left) and contaminated (right) oil samples

Transformer management software

Transformer management software has been developed to enable data to be introduced describing parameters related to transformer condition. This data is then used within a fuzzy logic model and output conditions were developed to give advice on the condition of the transformer.

The image shows a screenshot of a software application window titled 'MFL'. It features a table with columns for 'Nr', 'Date', 'Comments', and several gas parameters: Hydrogen, Methane, Ethane, Ethylene, Acetylene, CO, Combustible, Tg delta, Water, and Particles. The 'Chosen Oil Sample Status' is 'NORMAL' and the 'Last Oil Sample Status' is 'DEFECTIVE'. The table contains 18 rows of data, with the last row (Nr 18) highlighted. A control bar at the bottom includes navigation and editing icons.

Nr	Date	Comments	Hydrogen	Methane	Ethane	Ethylene	Acetylene	CO	Combustible	Tg delta	Water	Particles
2	2008-05-21	AFU-03	5	3	3	8	11	3	33			
3	2008-05-21	AFU-05	5	3	3	8	11	3	33	0.0036	4.2	50000
4	2008-05-21	AFU-04	5	3	3	8	11	3	33	0.0043	4.5	52500
5	2008-05-21	TRF-03	5	3	3	8	11	3	33	0.0083	35	83750
6	2008-07-02	before sample	9	2	24	7	5	42	89	0.053	17.1	77500
7	2008-07-03	TRF-01	9	2	24	7	5	42	89	0.0075	21.8	70000
8	2008-07-03	before sample	9	2	24	7	5	42	89	0.0077	15	73750
9	2008-07-03	TRF-64	9	2	24	7	5	42	89	0.0077	15	86250
10	2008-07-07	AFU-02	9	2	24	7	5	42	89	0.0067	6.7	85000
11	2008-07-07	AFU-01 start	9	2	24	7	5	42	89	0.0053	16.5	88750
12	2008-07-08	AFU 12:40	9	2	24	7	5	42	89	0.0057	9.9	86250
13	2008-07-08	TRF 13:45	9	2	24	7	5	42	89	0.0059	21	148750
14	2008-07-08	AFU-02	9	2	24	7	5	42	89	0.0057	10	167500
15	2008-07-09	AFU-03 8:45	9	2	24	7	5	42	89	0.0047	24.5	155000
16	2008-07-15	After AFU-01	9	2	24	7	5	42	89	0.0084	42.4	108750
17	2008-07-16	TRAFD bottom	9	2	24	7	5	42	89	0.0075	38.6	241250
18	2008-07-17	after AFU-01	9	2	24	7	5	42	89	0.0078	36.7	136250

Figure 4. Graphical user interface of transformer management software

The TRANSMAN project has delivered a compact, low-cost transformer insulation monitoring, conditioning and management system that has significant market potential.

Impact

The future impact of the TRANSMAN project will be associated with the New Knowledge generated from the project and the manner in which that Knowledge is taken forwards by the consortium. A summary table of the New Knowledge evolved by the project is found below;

Technology	New Knowledge	Pre-existing know-how owner	Rights agreement in place	Comments
Real-time particle sensor	Waveguide particle sensor for oil analysis	-	N/A	New knowledge protection with Exploitation Manager
On-line particle filtration system	Improved TRF product for oils	MinerWa/Pantreon	No	New Knowledge protection with Exploitation Manager
On-line moisture removal system	Moisture removal system for oils	-	No	New Knowledge protection with Exploitation Manager
Diagnostic Software	Transformer diagnosis software	IENOT	No	New Knowledge protection with Exploitation Manager

Table 1. New Knowledge generated from the TRANSMAN project

A project website has been put in place; www.transman.eu and an on-site transformer conditioning demonstration and case study has been undertaken, the results of which will be brought to the attention of key figures and providers throughout the power generation industry.

The achievements of the TRANSMAN project will be taken forward primarily by project coordinator Kelman Ltd, working together with project partners ESBI and IENOT, who are ideally placed within the power distribution industry to build interest in the TRANSMAN system as a valuable transformer management tool.

2 DISSEMINATION AND USE

Marketing Plan

The TRANSMAN project has the potential to extend the life of existing transformers by impacting positively on the current oil conditioning scenario. This will allow SMEs in the sector to contribute towards keeping maintenance costs to a minimum while enhancing the reliability of transformer substations and reducing capital expenditure.

Utility companies and private owners of distribution transformer networks (e.g. Rail Industry operators) will benefit from the reduced need for manual maintenance and the increased return on investment available by extending the life of their transformer assets. Better understanding of transformer condition monitoring will allow the operator to make value judgments on the ability of the transformer to be loaded beyond its rated value when required.

Communication of technology to the potential marketplace

The world of Power Engineering is very focussed on the activities of a number of key organisations. These organisations operate worldwide and regularly hold conferences, exhibitions and colloquia. They also publish journals which are read worldwide. Four key bodies have been identified that provide forums for dissemination of the potential benefits of TRANSMAN and these are listed below.

CIGRE (International Council on Large Electric Systems) is one of the leading worldwide organisations on Electric Power Systems, covering their technical, economic, environmental, organisational and regulatory aspects. A permanent, non-governmental and non-profit International Association, based in France, CIGRE was founded in 1921 and aims to;

- Facilitate and develop the exchange of engineering knowledge and information, between engineering personnel and technical specialists in all countries as regards generation and high voltage transmission of electricity
- Add value to the knowledge and information exchanged by synthesizing state-of-the-art and world practices
- Make managers, decision-makers and regulators aware of the synthesis of CIGRE's work, in the area of electric power

More specifically, issues related to planning and operation of power systems, as well as design, construction, maintenance and disposal of HV equipment and plants are at the core of CIGRE's mission. Problems related to protection of power systems, telecontrol, telecommunication equipment and information systems are also part of CIGRE's area of concern.

CIREN (Congrès International des Réseaux Electriques de Distribution). CIREN works for the purpose of increasing the business relevant competencies, skills and knowledge of those who see themselves as a part of the electricity distribution community, whether they are from the utility, product, consultancy, service, business or Academic sector. CIREN is dedicated to the design, construction and operation of

public distribution systems and of large installations using electrical energy in industry, services and transport.

CIREC covers;

- The whole field of Electricity Distribution Systems and associated services, including dispersed and embedded generation issues
- The technical aspects of Electricity Supply
- Related aspects such as cost reduction, environment, organisation and skills

To support its objectives CIREC's Technical Committee provides technical structure and content including papers and speakers to a biennial conference on developments and best practices in technology and management of electricity distribution. These conferences are open to participation by and contributions from experts from all over the world. The conferences which include an exhibition by manufacturing and other companies supplying the electricity distribution industry are organised alternately by AIM (Belgium) and IEE (UK) who also bear the financial responsibility of the conferences.

IEEE (Institute of Electronic and Electrical Engineers). Through its global membership, IEEE is a leading authority on areas ranging from aerospace systems, computers and telecommunications to biomedical engineering, electric power and consumer electronics among others.

Members rely on IEEE as a source of technical and professional information, resources and services. To foster an interest in the engineering profession, IEEE also serves student members in colleges and universities around the world.

IET (The Institution of Engineering and Technology). The IET aims to: To build an open, flexible and limitless global knowledge network supported by individuals, companies and institutions and facilitated by the IET and its members. It operates worldwide but its HQ is in London UK.

Through the activities of these organisations, several opportunities arise each year for presentation of technical and commercial papers and exhibitions. It is possible to penetrate the global market very effectively by the ability to engage directly with the decision makers in the power industry. **Key Dates to include in the commercial plan for TRANSMAN are shown below.**

- 2009 IEEE PES Power Systems Conference & Exhibition (PSC); a major power systems event that will take place at Washington State Convention & Trade Center in Seattle, Washington, USA, on March 15-18, 2009.
- 2009 CIREC Prague, Czech Republic. 8 - 11 June 2009
- 2010 CIGRE Session Paris, France. August 2010

Key journals to target with TRANSMAN developments

A number of key publications can also be highlighted and will be targeted;

Transmission & Distribution World is edited for engineers and operating professionals in the electric power industry. Feature articles are written primarily by technical editors and industry professionals in the user and manufacturer groups. Survey reports by the editors deal with industry practices and trends in specific areas. Yearly editorial content includes feature articles on electrical transmission & distribution, substations, construction, operation and maintenance, automation, and other articles pertinent to the electric power industry. Non-feature editorial covers new product reviews and industry news.

CIGRE ELECTRA is the bilingual journal of CIGRE. In total, 6 ELECTRA issues are published per year. The first one comes out in mid-February and then every 2 months.

Exploitation Plan

The TRANSMAN project was a very demanding project. The Consortium did achieve the goal of creating a system which, by processing the transformer oil and monitoring the process, will enhance the long term life of the transformer asset. But in order to progress to a satisfactory manufacturable and copasetic product, a considerable amount of further development and refinement needs to be undertaken.

In particular, the information gleaned during the on-site transformer case study undertaken in Lodz, Poland, highlights that a considerable benefit could be gained by immediately engaging with key transformer experts, discussing with them the significant points in our project and establishing a more demanding test case. Whether this should be done as an immediate step using the presently developed equipment, or a derivative based on that is a point for consideration. The immediate engagement of an organisation with a real requirement to enhance its approach to Life Management of transformers, who would be prepared to subject transformers in service to the oil processing proposed by TRANSMAN, would be an essential part of the strategy.

The commercialisation must stand alongside these developments, in order to create cash flow and to ensure that the process of development is based on sound understandings.

The TRANSMAN project has brought together methods for diagnosing transformer and transformer oil condition with methods of enhancing oil condition. There are clearly defined parts of the system which are potential stand alone products, as shown in Table 1. The value of each of these should be assessed and marketed. Each of these elements requires further development in order for a viable product to emerge. Consequently the exploitation programme is complex. The individual parts of the system must be matured and brought together when appropriate to build the system. The process is helped by the fact that each part of the total system can be perfected and marketed as separate entities.

For this to happen, there must be a commitment to further joint R&D work, and a suitable vehicle for this to happen, under EU facilitation would be to create an EEIG (**European Economic Interest Grouping**).

A **European Economic Interest Grouping** (EEIG) is a legal entity created under EU Council Regulation 2137/85. It is designed to make it easier for companies in different countries to do business together or to form consortia to take part in EU programmes. The activities of an EEIG must be ancillary to those of its members, and any profit or loss it makes is attributed to its members. Thus, although it is liable for VAT and employees' social insurance, it is not liable to corporation tax. It has unlimited liability. Several thousand EEIGs now exist, active in fields as varied as agricultural marketing, research and development, osteopathy, motorcycle preservation and cat-breeding. One of the more famous EEIGs is the Franco-German television channel ARTE.

This would open up the possibility of further EU funding for those parts of the technology that require substantial further work. This EEIG would then refine this exploitation plan and tune it as the product develops. It would also be able to release parts of the system as stand alone products as part of the strategy.

If an EEIG is not considered an appropriate vehicle, then a joint venture between a sub set of those members of the TRANSMAN project, with a commitment to succeed should develop and implement this plan. The grouping should only consist of those with commercial drive to succeed. There will be a need to fully consider the resource requirements and a full business plan will need to be created and reviewed as progress is made.

Knowledge Management Plan

In light of the existing agreements in place between members of the TRANSMAN consortium and the identified needs for further agreements to be put in place, the following Actions table has been evolved by the Exploitation Manager.

New Knowledge	Actions
Real-time particle sensor	Patent application to be initiated
On-line particle filtration system	Patent application to be made before we seek advice from transformer experts. Agreement required regarding the use of Pantreon's equipment.
On-line moisture removal system	Patent application re use of cellulose to dry transformer oil. Potential patent application regarding recycling.
Diagnostic software	IENOT to define the initial wording of patent and patent application will be initiated by exploitation manager..

Table 2. New Knowledge Actions

Conclusions

The TRANSMAN project has delivered a compact, low-cost transformer insulation monitoring, conditioning and management system that has significant market potential. The SMEs have collaborated on a Trans-European Level with great success and are committed to exploiting the TRANSMAN technologies

Acknowledgements

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