Institution: Newcastle University

Unit of Assessment: 10 Mathematical Sciences

Title of case study: Faster Fault Tracking for National Grid Gas

1. Summary of the impact

Statistical research undertaken by the *Industrial Statistics Research Unit* (ISRU) at Newcastle University has led to improved accounting of gas in the national transmission system provided by *National Grid*. A discrepancy, known as *unaccounted for gas (UAG),* results in accrued costs and potentially unfair billing. In 2009/10, UAG is estimated to have cost £100 million. *National Grid* has adopted our research results by making fundamental changes in their data utilisation with benefits that reach all the distributers and users of gas throughout the UK. In 2010 our methods helped identify a source of *UAG,* resulting in £14 million being returned to the community. Our reports inform decisions made by regulators and provide data-based evidence to support negotiations between national transmission, local distributors and users.

2. Underpinning research

The *Statistical Process Control* (SPC) and data mining techniques underpinning the fault-tracking procedures now employed by National Grid for their gas transmission system were developed by Coleman and Stewardson, members of the *Industrial Statistics Research Unit (ISRU*) at Newcastle University. In the period 1993-2001, new *SPC* methods were developed via research with unstable chemical processes [P1], agricultural equipment (with collaborators Malone R., Nelson T. & Bonta J., from USA) [P2], environmental data [P3] and business processes. One of the special features of this type of SPC was that it involved modelling individual measurements rather than the so-called rational sub-groups of measurements used in manufacturing. Coleman further developed this type of SPC for National Grid (NG) System Control, giving special consideration to issues such as prioritising error detection over the cost of responding to action signals [P4]. Our SPC methodology was successfully adopted by the four UK area gas control centres and was later jointly owned by Gas National Control Centre and Distribution Networks Control Centre to provide statistical monitoring of the movement of gas to detect whether processes are running as efficiently as possible [P5].

Our SPC for a safety measurement framework, developed in collaboration with NG [P6], required special consideration of short start-up times for annually collected data and low event rate for incident statistics, varying reporting periods, differences in data availability and quality, and issues of operational ownership. Our SPC work gave us considerable depth of knowledge of the gas transmission system. Further applied statistics projects included statistical analysis of extreme load values in 2004 with Transco (forerunner of NG), and Monte Carlo testing and surveying of assets with Advantica in 2003 and 2008. (Advantica was formed from BG Technology which employed the technical staff of Transco). These projects led to our successful on-going research with NG (from 2005) and the impacts from 2008.

Vast quantities of gas flow data, temperature, pressure and chemical measurements are collected every second by NG and used to control the system within strict guidelines. Gas flows from north to south and from east to west and can be stored offshore, in containers or by increasing pressure in pipelines. Gas flow data are seasonal and diurnal; the various meter readings give rise to multivariate, time dependent data. Unaccounted-for-gas (UAG) is the difference between meter readings from multiple inputs (approx. 30) and multiple outputs (approx. 200). It is of paramount

importance to NG to control and reduce UAG.

NG needs to identify meter errors causing changes in UAG and to detect patterns in UAG data both to improve their service provision and to meet regulatory obligations. Our time series analysis identified seasonal and temporal effects. Our application of techniques including principal components, regression, decision tree and cluster analysis is new for this type of auto-correlated, multivariate data and required special adaptation in terms of stopping rules and sub-division of clusters. We were able to highlight patterns in the data and provide evidence to support the decision to prioritise and carry out expensive investigations.

3. References to the research

[P1] Gardner, J.A., S.Y. Coleman and S.G. Farrow (1994), *Start with SPC and Save, Save, Save,* Analytical Proceedings of the Royal Society of Chemistry, 31, 71-74.

[P2] Malone R., Stewardson D., Nelson T. & Bonta J. (1999), *Calibration & Quality Control of the Coshocton Weighing Lysimeters*, Transactions of the American Society of Agricultural Engineers (Trans ASAE), 42(3) pp701-712, ISSN 0001-2351.

[P3] Stewardson, D.J. and S.Y.Coleman (2001) *Using the summed rank cusum for monitoring environmental data from industrial processes*, J. Applied Statistics, 28, 469-484.

[P4] Coleman, S. Y., Gordon, A., & Chambers, P. R. (2001). *SPC making it work for the gas transportation industry*. J. Applied Statistics, 343-351. [*Key reference]

[P5] Chambers, P. R., Piggott, J., & Coleman, S. Y. (2001). *SPC - a team effort for process improvement across four Area Control Centres*. J. Applied Statistics, 307-324. [*Key reference]

[P6] Coleman, S. Y., Arunakumar, G., Foldvary, F., & Feltham, R. (2001). *SPC as a tool for creating a successful business measurement framework*. J. Applied Statistics, 325-334. [*Key reference]

As a result of successful collaboration, Newcastle University were awarded successive contracts in excess of £150,000 for research into the causes of variation in UAG and the application of data mining methods.

4. Details of the impact

National Grid (NG) provides the gas transmission infrastructure for the entire country whilst gas distribution networks link this infrastructure to users. Within this transmission system, a sustained level of discrepancy exists in the accounting of gas, leading to *Unaccounted for Gas* (UAG). Identifying and reducing UAG is of major importance to NG and its regulator, the *Office of Gas and Electricity Markets* (OFGEM) [E3], as it is a sign of problems such as meter error and results in accrued costs and potentially unfair billing. In 2009/10, the volume of UAG was estimated at 7720GWh (total cost of £100million [E1. Pg1]). Tracking down the source of UAG can be difficult as the causes may include shrinkage, weaknesses in measurement or accounting processes.

The research conducted by the *Industrial Statistics Research Unit* (ISRU) at Newcastle University has produced effective data mining methods for revealing hidden patterns and detecting their causes. The resulting tailored analysis and data mining software has changed the way professionals utilise the data [E4] making it feasible to extract valuable information from operational gas flow data and help National Grid (NG) deal with the issue of *Unaccounted for Gas*. Although current methods employed by their staff were effective, NG felt that they could be improved and invited Coleman (from 2008 onwards) to explore the application of statistics and data mining on

energy balance data to gain further advantage.

Newcastle University has helped NG significantly reduce the volume of UAG with benefits that reach to all providers and users of gas throughout the UK. The research has led to a step change in the processes that NG use [E2, E4] to utilise their data and the related working practices. The new decision tree analysis methods helped identify a source of UAG in 2010, resulting in £14 million being returned to the community in a single year [E1, pg. 4]. As a result of the benefits achieved by initial changes, NG have adopted these procedures and staff-training in the statistical and data mining methods developed at Newcastle University have been introduced ensuring our work continues to have a lasting effect. The 2013 UAG report shows a further reduction of over 20 million kWh of UAG since 2010 [E2, pg. 10] and notes the discussions with ISRU and the potential for further investigation to identify UAG causes.

In addition to the benefit of better accounting, some further impacts are presented below:

Improving accuracy of leakage estimates

Our work validating the collection of information to determine accurately the volume of gas lost from the system due to leakage from assets and the statistical findings provided a sound basis for investment in leakage strategies. The leakage rates were used to develop a *shrinkage model* (National Leakage Reduction Monitoring Model) which is currently used by all of the UK Gas Distribution Networks, to estimate the impact of mains replacement on leakage, as corroborated in [E5].

In [E6, pg. 35, 2011], it is stated: "*Given the rigorous assessment of the sampling, collection and analysis of results carried out in the National Leakage Survey 2002/3, and the assessment by the ISRU, the AUGE believes the leakage rates used by the GTs for the calculation of shrinkage are reliable and unbiased*" and "*The leakage rates have a 90% confidence interval of ±19.4%*". AUGE is the Allocation of Unidentified Gas Expert and GT refers to Gas Transporters (including Gas Distribution Networks whose assets link NG's transmission pipelines to end users). This work, in 2010 has been highlighted as an exemplar of research with direct economic impact by the Russell Group [E7, pg. 15].

Improving the safe management of the system

Our work has been instrumental in achieving a transformation in the use of statistics to support operational and management decision-making [E2, pg. 23]. Newcastle University's *Statistical Process Control* (SPC) charts provide immediate insight of safety performance by charting measurements with control limits. Dashboard presentation continues to be valued as corroborated in [E4] which states that SPC charts are "*a powerful management decision making tool*" and that the methods "*continue to have a positive impact on the safe and efficient management of the UK gas transmission system".*

Improved monitoring of UAG levels & better stakeholder relations

We created a process flow map for UAG used by NG [E3] which includes all steps in the gas transmission process; each step has been examined in terms of stakeholders and influences. Our work is essential because it helps distinguish periods when UAG is stable and periods where there are statistically significant changes. Therefore when a significant change arises, staff can identify the likely causes and prioritise which meters to investigate; they have evidence to empower them, which has led to a better dialogue with meter owners and more effective problem solving.

NG professionals have used our research findings to be confident in their estimates of the contribution of UAG from the transmission system and to develop effective communication

between the different stakeholders. The software and statistical advice continue to have a positive impact on the assessment and exploration of UAG as corroborated in [E3].

Newcastle University research has contributed to NG's good relations with OFGEM and the Health and Safety Executive. Our work has led to a high standard of data investigation, and to NG being credited for their sound scientific approach. Our reports have been used to show how serious NG are about continuously improving their processes, particularly during negotiations on pricing and other control policies, for example [E6, see pg. 35 & 36].

5. Sources to corroborate the impact

[E1] Open letter from National Grid to Shippers, Suppliers, Customers, Transmission and Transportation System Owners and other Interested Parties (2011) http://www.nationalgrid.com/NR/rdonlyres/07E7A1E2-7982-48FE-9A5D-F6ACB634F49D/47329/UAGIndustryUpdateJune2011.pdf. [accessed 13/02/13]

[E2] Unaccounted for gas report, National Grid (2013). http://www.nationalgrid.com/NR/rdonlyres/6C31A7B2-6F15-4665-ACCD-BAA61BB98563/58740/UAGReportFebruary2014.pdf. [accessed 22/04/13] *This document is published to meet special condition C29: Requirement to undertake projects to investigate the causes of Unaccounted for Gas (UAG).*

[E3] Letter of support from UAG Project Manager, National Grid (2011).

[E4] Letter of support and comments regarding on-going use of SPC in system control from *Rune Associates* (2011).

[E5] Corroboration from Senior consultant, Utilities Practice, GL Noble Denton (2013).

[E6] Report: *Allocation of Unidentified Gas Statement*, GL Noble Denton (2011), http://www.gasgovernance.co.uk/sites/default/files/2nd%20Draft%20AUGS%202011%202.0.pdf. [accessed 13/02/13].

[E7] Case study 9: A statistical methodology for asset surveys. In *The economic impact of research conducted in Russell Group universities*. Russell Group Papers – Issue 1, Page 15. Russell Pioneering Research Group, (2010). www.russellgroup.ac.uk/uploads/RG_ImpactOfResearch2.pdf. [accessed 17/07/13]