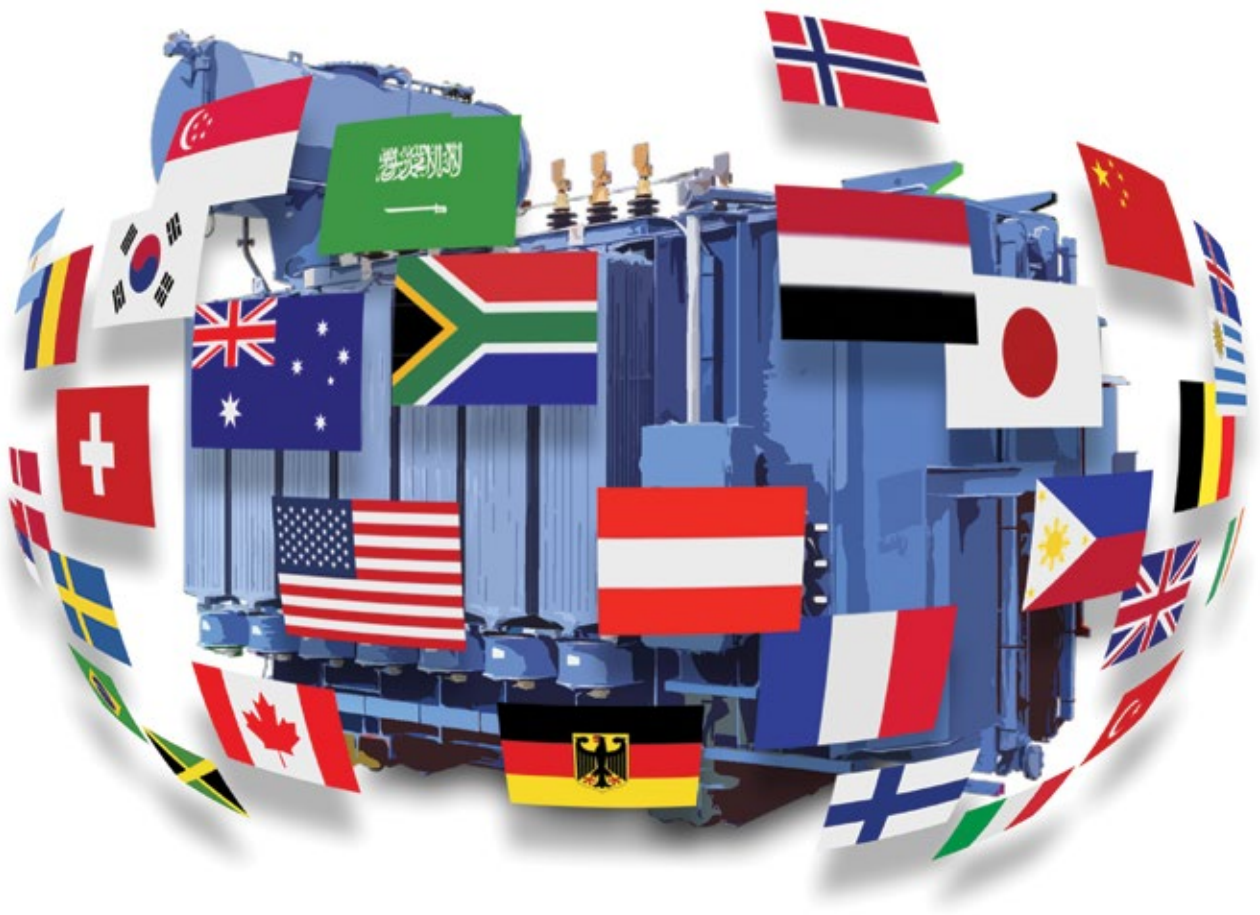

Transformer market report: What is the uncertainty of the reported market size?

ABSTRACT

For the last two years, the global transformer market has been characterised by high demand and rising prices, caused on the one hand by the ongoing transformation of the electricity grid and the electrification of various appliances, such as EVs, and on the other hand, by a large rise in materials costs. This combination has caused an increase in the market's value from 2020 to 2022 by about 50 %, to almost $60 billion. Various market reports present different numbers without indicating the expected accuracy of the data presented. Statplan has carried out a detailed analysis in its latest report, Ed. 11, and presents the methodology for the determination of accuracy and the outcome in this paper. The market analysis covers low voltage transformers >1 kVA, and medium and high voltage distribution and power transformers.

KEYWORDS:

transformer market, accuracy, uncertainty, expected error

The COVID-19 pandemic caused a slight drop in the global production and sales of transformers in 2020 compared with the previous year

1 Introduction

The COVID-19 pandemic caused a slight drop in the global production and sales of transformers in 2020 compared with the previous year. It also caused significant disruptions to supply chains. Combined with a strong increase in demand and the problems originating from the Ukraine war, the prices of materials have increased significantly during the last 2 years but are now stabilising. The increased materials costs and the strong market were reflected in transformer prices. Statplan has determined the global market for transformers >1 kVA, including low, medium, and high voltage distribution and power transformers, as being $39.6 billion in 2020, $48.2 billion in 2021, and $59.6 billion in 2023. The forecast for 2028 is $87.8 billion [1].

It is very rare that a market can be determined precisely without any uncertainty. Since there are usually large numbers of players active in a market (vendors, purchasers, intermediaries, etc.) and they are not interested in publishing their business numbers, even if those numbers were to be published, they might contain errors, the determination of market size must be regarded as a best guess estimation, with a certain degree of accuracy, but not as an exact value. The question is how should the accuracy of the market numbers given above be estimated. Accuracy is defined as:

Best guess market estimation = exact market size ± accuracy

The previous paper published in Transformers Magazine presented how Statplan determines the transformer market size [2] in its report (Ed. 10) by applying a methodology using electricity consumption. The transformer market size is determined by country and segmented into central generation PT (PT = power transformer: >10 MVA or >36 kV), grid PT, distributed generation DT (DT = distribution transformer: ≤10 MVA or ≤36 kV) and grid DT. DTs are further broken down into oil-filled DTs and medium-voltage and low-voltage dry-type transformers.

Depending on the country and type of transformer, the market data is deduced in one of three ways: either from a top-down approach (installed power generation capacity, electricity consumption), from a bottom-up approach (transformer manufacturers' data combined with import/export data), or from an approach utilising published national figures (inventory data of electric transmission and distribution companies, or industrial or governmental statistics, or other sources), or a combination thereof. A specific transformer manufacturer's annual financial report may be available; if not, the production volume needs to be estimated. In both cases, the data contains some uncertainty. In the former case, the total sales presented in an annual report may contain data on some other lines of work, e.g., transformer service and repair works or additional products like compact substations. In the latter case, the error in estimation depends on how well the editor of a market report knows the specific company and its recent development.

More and more, market reports are prepared simply by obtaining information from the Internet. The editors of those reports usually do not have any specific transformer market knowledge, and the accuracy of the data is in line with this. It is axiomatic that the quality of a research study depends on the data it is based on, but there are inevitably some gaps and inconsistencies in the input data. Scientists and engineers encounter this problem as a matter of course, and they evaluate the accuracy of a project using well-tried statistical analysis. We think it would be very useful if, in future, all market reports specify the accuracy of their market data estimations.

2 The calculation of accuracy

Transformer market figures are derived from some other figures by a mathematical operation; i.e., there is a function to define dependency: f(x,y,z…).

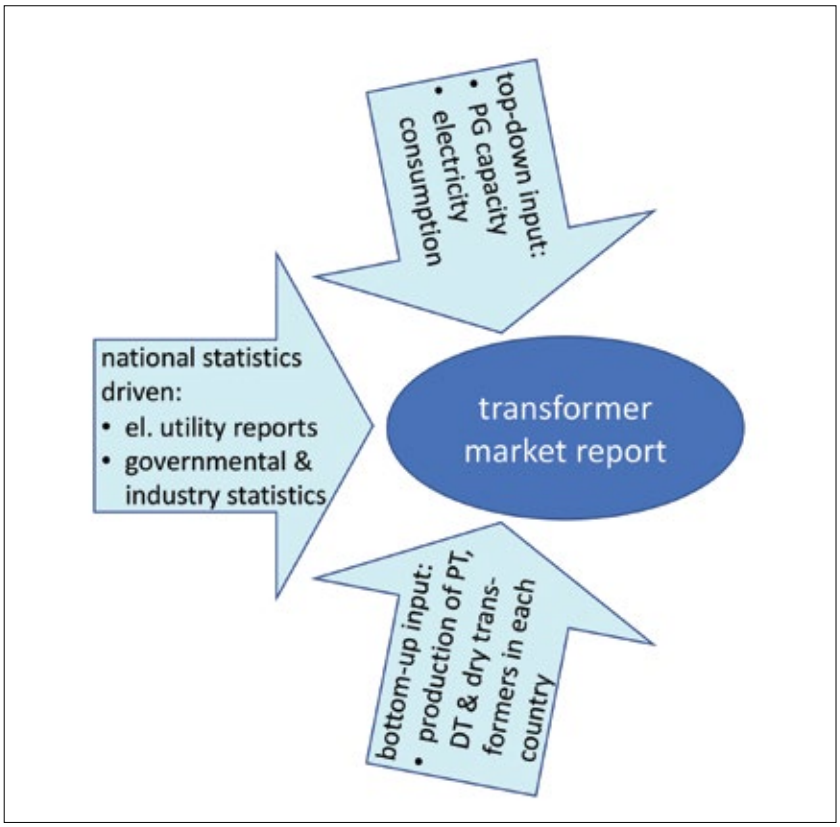

Figure 1. Input data used for the preparation of the transformer market report

More and more, market reports are prepared simply by obtaining information from the Internet, while the editors of those reports usually do not have any specific transformer market knowledge

Those other numbers (variables x,y,z,…) can be known with a certain degree of accuracy or error. Such accuracy typically has the meaning of a standard deviation; i.e., in a statistical distribution, a measured value has a probability of 68 % of being within a range of the exact value +/- the accuracy. If the error or accuracy (dx, dy, dz, ...) of the variables is not known, a way to determine it must be found. "Error" and "accuracy" have similar meanings and are often used interchangeably. The error indicates the difference from an exact reference value, while accuracy is used if an exact value is not available or cannot be determined but relates to a most probable value.

In physics, the determination of an error is normally done by repeating an experiment multiple times and checking for systematic errors, e.g., by using different measurement instruments. For market data, this could be done by comparing the data from different sources, looking at historical developments, or analysing the background of a number in depth. If nothing is available, a best guess estimation can be used, but in that case, the relative error will usually become rather large.

The calculation and propagation of errors (uncertainty) is a well-established method. For our function, f, the uncertainty df is calculated as:

$$df = \sqrt{\left(\frac{\delta f}{\delta x}dx\right)^2 + \left(\frac{\delta f}{\delta y}dy\right)^2 + \left(\frac{\delta f}{\delta z}dz\right)^2 + \cdots} \quad (1)$$

Where $\frac{\delta f}{\delta x}, \frac{\delta f}{\delta y}, \frac{\delta f}{\delta z}$, are the partial derivatives of the function f.

In the following cases, we use an additive or a multiplicative function for further derivation of the error calculation formulas.

2.1 Sum of values: Market calculation based on the additive function — production, import, and export

The market M of a country can be estimated by adding the local production volume to the import volume and subtracting the export volume. This requires that individual manufacturers and their approximate production volumes are known with reasonable accuracy.

$$M = P + I - E \quad (2)$$

where P = production, I = imports, E = exports.

The total production $P = \sum_x p_i$ and p_1, p_2, p_3, p_i, … represent the production of each company in a country.

The total production error, dP, is calculated from the production estimation accuracy, dp_i, of each company.

Figure 2. Transformer at the Mattmark hydropower station Stalden in Switzerland

The market of a country can be estimated by adding the local production volume to the import volume and subtracting the export volume

$$\sqrt{dp_1{}^2 + dp_2{}^2 + dp_3{}^2 \ldots .} \quad (3)$$

Market size accuracy is calculated as follows:

$$\sqrt{dP^2 + dI^2 + dE^2} \quad (4)$$

with dI and dE being the import and export value errors.

2.2 Product of values: Market calculation based on the multiplicative function — produced capacity and price

The market is determined as follows:

$$M_{USD} = M_{kVA} * sp \quad (5)$$

where M_{USD} is the market in USD (or another currency), M_{kVA} is the market size in transformer capacity, kVA and sp is the specific price in USD/kVA, having an uncertainty of dsp. In this case, the dM_{USD} error is calculated as follows:

$$dM_{USD} = \sqrt{(M_{kVA} * dsp)^2 + (sp * dM_{kVA}))^2} \quad (6)$$

with dM_{kVA} being the annual market capacity size error.

2.3 The total market error

As indicated above, the dM_{USD} error is calculated for each of the four transformer categories and for the two main sub-groups: liquid transformers (PT and DT) and dry transformers (MVdry and LVdry).

$$dM_{USD}(liquid) = \sqrt{dM_{PT}{}^2 + dM_{DT}{}^2} \quad (7)$$

$$dM_{USD}(dry) = \sqrt{dM_{MVdry}{}^2 + dM_{LVdry}{}^2} \quad (8)$$

Finally, the total market error, $dM_{USD}(total)$ is calculated as follows:

$$dM_{USD}(total) = \sqrt{dM_{USD}(liquid)^2 + dM_{USD}(dry)^2} \quad (9)$$

3 The accuracy of market data

In the following examples, the above formulas have been applied and discussed, and the examples for the determination of the errors regarding the variables have been given. Note that mostly generic data has been used for illustration purposes.

3.1 Market calculation based on production, import, and export

As was described, to obtain the market value, the total production volume (in USD) in a country needs to be estimated and modified using the import and export volume. Depending on the country, there may be a small or large number of manufacturers. The production volume of each manufacturer needs to be estimated, along with an estimation of the accuracy of that estimate. In order to do this, sound market knowledge is required. For larger conglomerate companies, for example, the transformer business is only a (small) part of their overall revenue, so if their total revenue is attributed to transformers, the outcome is not meaningful. On the other hand, due to the laws of statistics and error propagation, even though individual companies can have quite high uncertainty, on an aggregated level, the relative estimation accuracy for the country can become reasonable. This is illustrated in the example in Table 1, where the estimation error of the volume of some of the companies was 50 % or 100 %. Despite this, following the application of equation (3), the accuracy for the whole country became 23 %.

The production volume of each manufacturer needs to be estimated, along with an estimation of the accuracy of that estimate

Table 1. Example of how the rather large sales volume estimation errors of individual companies translate into a reasonable relative error for the total production in a country.

Production	Sales	Error	Relative error
Manufacturer 1	100	50	50 %
Manufacturer 2	80	40	50 %
Manufacturer 3	80	20	25 %
Manufacturer 4	30	30	100 %
Manufacturer 2	30	5	17 %
Total production	**320**	**74**	**23 %**

Table 2. The import and export volume in 2021 for Germany, Greece, Mexico, Turkey and the UK for oil-filled power transformers >10 MVA, reported as imports by those countries and as exports from all other countries and the accuracy of impex data derived thereof

Country	Import to a country (MUSD)			Export from a country (MUSD)		
Reporter	Country	All others	Accuracy dI	Country	All others	Accuracy dE
Germany	86.4	103.4	10	261.3	210.0	30
Greece	25.4	35.8	5	1.7	0.0	1
Mexico	9.4	14.9	5	234.3	278.3	30
Turkey	0.0	14.2	5	302.7	174.8	70
United Kingdom	57.9	99.3	25	23.7	9.8	10

TSO or DSO companies often indicate the total capacity of power or distribution transformers installed in the grid in their annual reports

The import/export trade data is collected by almost all countries and reported to UN Comtrade, which makes the data publicly available (see reference [3]). It is not obvious what the accuracy of this data is. Looking through the detailed statistics of various countries, one can find apparently inconsistent records which do not appear meaningful, e.g., if there is an export from a country which does not have a transformer industry and if it is unlikely that the country is a destination for re-exports or serves as a country of consignment.

In order to produce an idea regarding the accuracy of reported trade data, we started to compare two different sets of reports. For the imports to country A, these are:

- the imports reported by country A
- the exports to country A reported by all other countries

It is clear that these two numbers will not match exactly. There are a number of reasons for this, and a discussion of them would warrant a separate paper. One of the reasons is that the Incoterms for the reported export data is FOB, while, for import data, it is CIF. The value of imports should, therefore, be higher than that of the exports. This is not always the case due to other reasons. Nevertheless, a comparison of the two values, combined with the review of imports and exports to and from individual countries and an assessment of how probable they are, indicates the accuracy of trade data (Table 2). As already mentioned, the indicated accuracy has the meaning of a standard deviation.

The analogue comparison is also applied to determine the accuracy of exports. Using this approach, market accuracy, based on a generic example, has finally been reported in Table 3.

Table 3. Example for the determination of the market size and the related accuracy

	Value	Accuracy	Relative accuracy
Production	320	74	23 %
Import	100	30	30 %
Export	-50	10	20 %
Market	370	80.5	21.7 %

Table 4. Generic example of the market size accuracy calculation, determined from the transformer capacity and the price per kVA

Unit			Accuracy
Change of installed capacity	kVA	2,500,000	1 %
Additional replacements	kVA	1,000,000	25 %
Other markets	kVA	500,000	50 %
Total market in kVA M_{kVA}	kVA	4,000,000	8.9 %
Specific price	USD/kVA	13.0	20 %
Market in USD M_{USD}	USD million	52.0	21.9 %

3.2 Market calculation based on MVA and price

TSO (Transmission System Operator) or DSO (Distribution System Operator) companies often indicate the total capacity of power or distribution transformers installed in the grid in their annual reports. Those numbers are expected to be precise, with low uncertainty. The transformer market in kVA (or MVA), MkVA, can be estimated for the utilities as the sum of new purchases plus replacements, and in total by adding sales to other owners, often called 'industry' but also includ-

Based on these principles, it has been calculated that the 2021 global transformer market size uncertainty is 9 %

Figure 3. Wind farm substation transformers (photo courtesy of SGB-SMIT)

Table 5. Global transformer market size 2021 and related accuracy

Global market	Market size $ billion	Accuracy $ billion	Relative accuracy
Total market	48.2	4.3	9 %
Oil-filled transformers	35.3	4.0	11 %
Dry-type transformers	13.6	2.1	16 %

ing other entities. New sales amount to the installed base at the end of the previous year, less the base of the previous year. A similar calculation is employed for the replacements but using the base at the time of installation, i.e., 25/30/40 years ago. The replacement rate is high compared with new sales in a mature market but low in a growing market, such as a developing country. Transformer ownership by non-utilities is estimated from various utility reports and industry studies, mainly on transformer efficiency.

The estimation of replacements and the sales volume to other than electric utility customers will have some uncertainty. The total market accuracy, dMkVA, is calculated according to equation (3).

For the calculation of market values in USD or another currency, MUSD, the market size in kVA, MkVA, needs to be multiplied by the price per kVA (specific price). Since PTs and DTs are normally customised products whose prices are not public, the specific price is an estimation containing some uncertainty. Table 4 gives an example of such a calculation.

3.3 The uncertainty regarding global transformer market numbers

Based on these principles, it has been calculated that the 2021 global transformer market size uncertainty is 9 % (Table 5).

Since at the time the Statplan Ed. 11 report was being prepared, annual company reports, impex and other data for 2022 were not yet published, the accuracy of 2022 market numbers was not yet determined. Due to the need to use somewhat larger uncertainties when it comes to the various variables, the total market uncertainty in 2022 would also be somewhat larger.

As for the individual countries, the total transformer market uncertainty varies between 4 % to 5 % for large countries like the USA and Japan, which have a lot of available information, and more than 100 % for small countries, which have limited information available and large year-to-year variations.

Conclusion

For the first time in a transformer market report, the determination of uncertainties regarding the input data and the application of error calculations have been applied. This has resulted in an indication of the reported market data accuracy and provided the reader with additional information, helping to assess the quality of a market report. As for the Statplan report, it has been determined that the accuracy of the global transformer market size is 9 %.

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Authors

Martin Carlen completed his PhD in atomic physics in 1992. After a postdoc at the National Renewable Energy Lab in Golden, CO, USA, he worked at ABB Corporate Research in Switzerland, where he became Head of the Electrotechnologies Department. He continued his career as Global Product Manager for dry-type transformers at ABB. In 2016, he became the Head of Business Development and the Head of Operational Excellence of SGB-SMIT Group, Regensburg, Germany. Since 2021, Martin has owned his own company, "SISTEMA Consulting".

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