New methodologies in transformer market investigation

The StatPlan Transformer Report, 10th Edition, 2022

Photo courtesy of SGB-SMIT Group

ABSTRACT

In 2020, the global market for power and distribution transformers fell from $43.4 billion in 2019 to $39.8 billion as the Covid pandemic peaked, but it rose again to $49.3 billion in 2021 and is forecast to reach $70.4 billion in 2027. The increase in 2021 was partly due to recovery from the Covid low of 2020 but also because of price rises of materials in the latter half of 2021. The value in 2021 was 24.0 % higher than in 2020, but the volume was only 6.2 %. New methodologies reveal that the global transformer capacity of distributed generation rose at twice the rate of central generation, 254 % in ten years compared with 128 %.

Euan BLAUVELT, Martin CARLEN

In 2020, the global market for power and distribution transformers fell from $43.4 billion in 2019 to $39.8 billion as the Covid pandemic peaked, but it rose again to $49.3 billion in 2021 and is forecast to reach $70.4 billion in 2027

A new definition has been introduced - power transformers have a capacity of 10 MVA or above, a voltage of 36 kV or above, and distribution transformers under 10 MVA and under 36 kV

1. Introduction

It is demanding to determine the global and national market sizes for a product that is needed everywhere, where hundreds of manufacturers compete globally and where markets are multinational and intercontinental. Deep knowledge of power systems, products, and markets is needed for a correct and relevant analysis of data. In order to determine good market data, it is important to have a good understanding of the environment in which the components are used. In general, the market size can be determined top-down, i.e., from the application side or from the bottom-up, corresponding to the manufacturers' output. The holy grail is to obtain a consistent outcome from both approaches. In this paper, we use India as an example to illustrate the deduction of our market data. We also present a short description of its power system.

The first edition of the StatPlan Transformer Report was issued by StatPlan Energy Research Ltd in 2012. The transformer bases were sized in the transmission and distribution networks globally for regions and major countries. The data basis of this and the following eight annual editions of the report has been generating capacity and utility and other reports of transformer MVA capacity [1]. Transformer capacity in MVA was estimated by applying factors to generating capacity for each segment: generation, transmission, and distribution.

StatPlan maintains a database for every country of generating capacity by energy source from 1990 to date and forecast to 2030, with total annual capacity recorded back to 1900. The factors for calculating MVA capacity were established from utility data, international sources such as IEA and EIA, and a number of transformer manufacturers provided information. Price analysis charted the large rise in material costs in 2008 and 2009, followed by stability. Demand was forecast in MVA and value, based on new installations and replacements to determine long-term trends, and modified with interviews and market knowledge for short-term sales. The reports evolved with more analysis.

Over the years, increasing amounts of data became available, and we have databases of capacity and unit numbers of utility distribution transformers in all countries. There is plentiful information about MVA capacity in the networks but less for units. A gap existed for industry-owned transformers, about which very little information is publicly recorded. In the 2000s, interest quickened in distribution transformer efficiency, and a number of studies published survey data on industry-owned distribution transformers, enabling us to create multiples to apply to utility data to estimate industry-owned capacity globally.

2. New methodologies in transformer market investigation

2.1. The need for a new methodology

The last two years, from the end of 2019 to 2021, were a period of exceptional disruption in the energy systems around the world due to the Covid pandemic, and new disruptions have appeared with the Ukrainian war, the Russian gas supply crisis, and the surge of renewables. As these disturbances started, a structural change was already emerging in the electricity supply system with the growth of distributed generation. Methodologies applied in the past no longer had sensitivity to changes in the composition of the market. The definition in previous studies segmenting transformers by their function as transmission or distribution as used by electric utility companies, but not according to capacity or voltage, does not provide a clear separation and differs from what transformer manufacturers are using. A new definition has been introduced; power transformers have a capacity of 10 MVA or above, a voltage of 36 kV or above, and distribution transformers under 10 MVA and under 36 kV. With this definition, power transformers can be used at the top end of some distribution systems. The same definition is used for the distinction between central and distributed generation, CGSU, and DGSU (see Fig. 1 for definition).

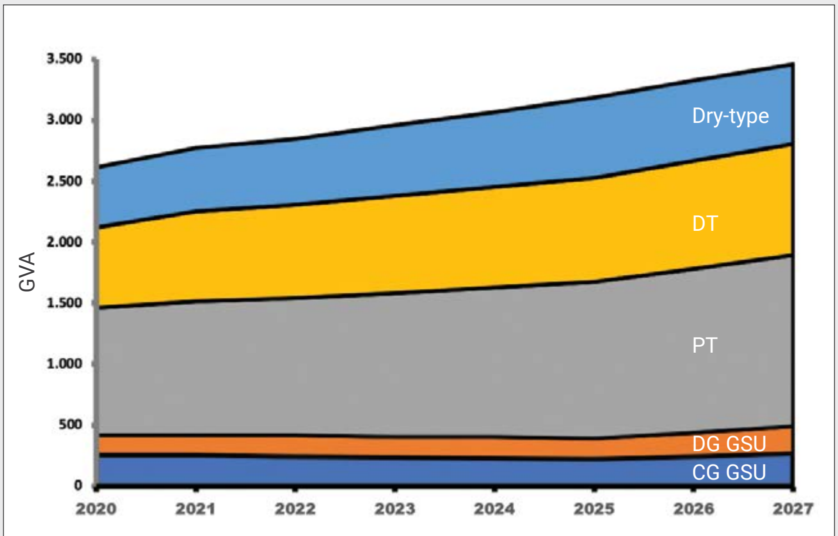

Figure 1. The growth of the global transformer market (MVA)
Note: PT – network liquid power transformer ≥ 36 kV, ≥ 10 MVA
DT – network liquid distribution transformer, < 36 kV,< 10 MVA
CGSU – central generation step-up transformer ≥ 36 kV, ≥ 10 MVA
DGSU – distribution generation step-up transformer < 36 kV,< 10 MVA
Dry-type – MV or LV dry-type transformers

Figure 2. Installation of 25 MVA transformer in Grindelwald, Switzerland (photo BKW, Switzerland)

When transformers are installed, engineers calculate the amount of capacity required based on average and maximum load, not nameplate generating capacity. Despite this, estimates based on multiples of generating capacity are reliable when generation follows a stable path, but it is now subject to two distortions:

New models have been created for installed capacity, the annual market, and transformer market forecasts, which are interlinked, but each measures a different characteristic

1) Consumption is growing in developing countries but declining in advanced countries. This is reflected in the consumption data but not in installed generating capacity, sometimes even in reverse. The sudden acceleration of DER (distributed energy resources) and renewables means that in many countries, MW is increasing rapidly, but because capacity factors and capacity credits are low compared with conventional energy sources, consumption may continue to fall, and new transformer capacity in the grid is not required. The result is increased generating capacity not accompanied by increased grid transformer capacity.
2) The growth of distributed generation is already causing a realignment from power to distribution transformers as more power is fed into distribution networks at medium voltage.

These two trends have impaired the estimation of transformer capacity from installed generating capacity. Therefore, a complementary and superior methodology estimates it from electricity consumption, including both utility and private consumers.

2.2. Overview of new methodologies

Three new models have been created for installed capacity, the annual market, and transformer market forecasts. These are interlinked, but each measures a different characteristic, and different data resources are used; total generating capacity, generating capacity analysed by energy source, utility transformer capacity, consumption, production, imports and exports, transformer prices, materials' prices, and analysis of distribution substations.

1. The generation sector is changing, with distributed generation increasing faster than a central generation, changing the composition of the power and distribution transformer base. A new model records the trends of generation capacity in MW analysed by energy source. The capacity of each energy source is assigned shares of central or distributed generation and factors applied to calculate central or distributed transformer capacity in MVA historically from 1990 to 2030. The details of this model are explained in paragraph 4.1.
2. A model estimating the installed base of PT, DT and MV and LV liquid-filled and dry-type transformers. In previous editions, coverage was limited to grid-side transformers "before the meter," but for Edition 10, 2022 [1], coverage has been expanded down to LV transformers over 1 kVA, on the energy

StatPlan has maintained a database of generating capacity for 184 countries, with total capacity from 1900 forecast to 2030, analysed by energy source from 1990 to 2030

users' side of the meter mainly in the industrial and commercial sectors, consisting of transformers required to change the utility distribution voltage to a voltage that is usable within the building.

3. A rigorous new model was needed to forecast transformer capacity and value, taking input costs into account. A two-stage approach was adopted. First, the transformer market value for each country was forecast to 2027 from the base year, 2020, at constant prices based on electricity consumption trend analysis. Second, the transformer value was disaggregated into six cost components, labour, materials, and overhead. The value of each component was weighted by expected cost increases to give the nominal market value. A detailed account is provided in paragraph 4.7.

The market in the base year 2020 is estimated from production plus imports minus exports or alternatively from new additions plus replacements. A more rigorous approach was developed for this, involving greater attention to production and trade sources.

3. The data resources

3.1. Generating capacity database MW

The analysis of distributed generation requires detailed information on the energy sources. The data for renewables is detailed because of different subgroups of the same renewable source feed power to the transmission and / or distribution networks. Distributed generation is not confined to renewables but has always been a segment of hydrocarbon and small hydropower. In the case of hydrocarbons, this has usually consisted of diesel, HFO (heavy fuel oil), LFO (light or extra light fuel oil), and small coal and natural gas engines or turbines. StatPlan has maintained a database of generating capacity for 184 countries, with total capacity from 1900 forecast to 2030, analysed by energy source from 1990 to 2030. The forecasting method is a combination of trend analysis, projecting to official targets stated by government energy authorities within national energy policies and assessing them on the basis of past achievements in meeting targets, updated according to current events such as the impact of the green lobbies on hydrocarbons (especially coal), nuclear and renewables, the Ukrainian impact on oil and gas supply from Russia. The IEA (International Energy Agency), EIA (Energy Information Administration - US Department of Energy), BP (British Petroleum Plc.), IRENA (International Renewable Energy Agency), and the UN (United Nations) all publish international analysis of generating capacity, but none is detailed enough for our purpose. The StatPlan database was updated, and the analysis expanded, adding several more subgroups of renewables. The database lists six conventional energy sources, including hydro and pumped storage, and eleven renewable categories. This database was the basic resource as data input for the model plotting the development of distributed and central generation.

3.2. Annual electricity consumption GWh

There are many reports of consumption, and few contain identical numbers because of different recording procedures and definitions. Times vary - some countries use the financial year ending in March (e.g., Japan and India), others the calendar year ending in December, and consumption is not the same in summer and winter, sometimes by a large margin. The points of measurement vary at the point of supply or at delivery after network and distribution transformer losses. Table 2 compares the consumption data for the UK published by the international sources IEA, EIA, and DUKES (Department of UK Energy Statistics).

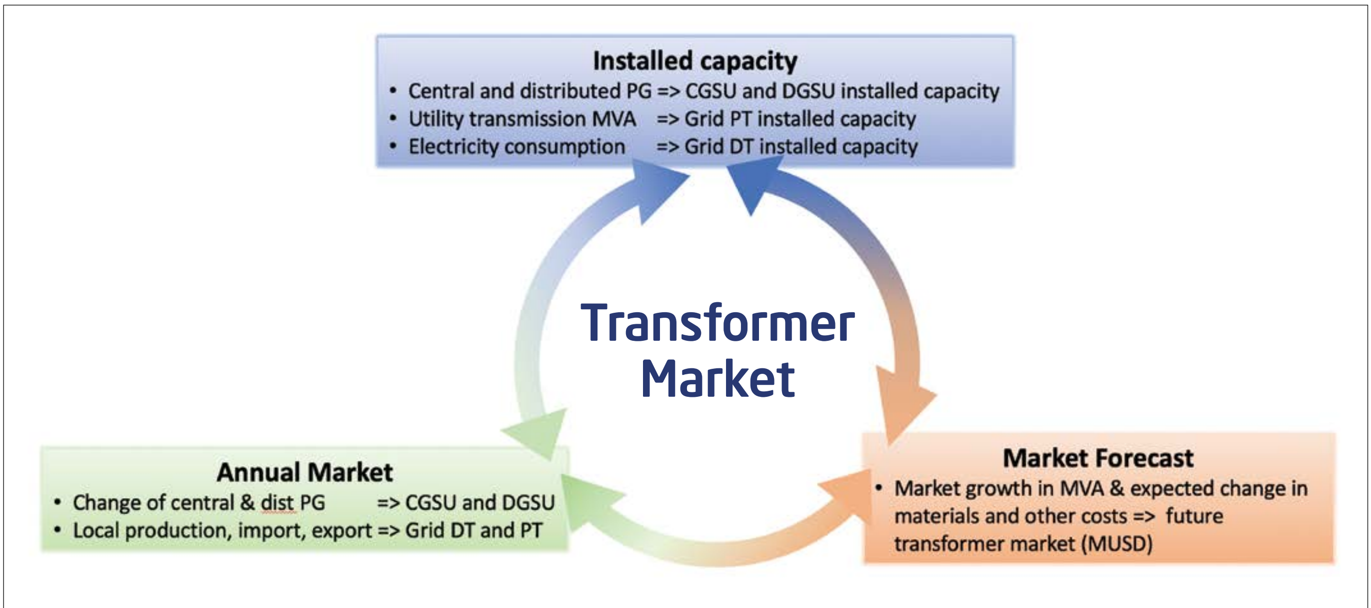

Figure 3. Linkage of the market numbers measured and the resources employed (Source: SISTEMA Consulting)

EIA and DUKES consumption figures are net, and IEA does not specify which.

For comparability, we have used IEA figures [2]. In some cases, the IEA does not publish analysis by end users, and we have used national analysis for this.

3.3. Distribution network topology

The network topology of every country is individual, both for transmission and distribution. The most fundamental difference is between North American and European systems. North America uses a mains voltage of 120/240/400 V, and Europe has a mains voltage of 240/400 V. The rest of the world mostly uses either these systems or derivatives of them. In the developing world, designs were influenced by the systems used by the colonial powers, namely Great Britain, Spain, France, and the Netherlands. The size of a country tends to influence the complexity of the system, but this is not always the case. The three largest countries - the USA, China, and India - have large networks. The USA has 520 transcos (electric utility transmission companies) and 2,300 discos (electric utility distribution companies), China has 2 huge T&D utilities with 31 transmission subsidiaries and around 3,000 discos, India has one backbone bulk transfer grid, 22 transcos, and 51 discos. The USA and India have diverse systems in operation by the individual utilities, but each has a dominant distribution voltage of 11–15 kV, with some primary and secondary MV substations. China has a more uniform distribution network, with the majority of lines operating at 10 kV and power being fed in direct from 220 or 110 kV substations. A few large cities have legacy substations at 35 kV, but the government is getting rid of these in order to reduce the number of steps in voltage reduction. With such diversity around the world, it is necessary to address the calibration of the MVA capacity of every country individu-

There are many reports of consumption, and few contain identical numbers because of different recording procedures and definitions

Table 1. The generating capacity database spanning 30 years for 184 countries (MW). The table shows the global installed capacity

MW	1990	2022	2030
Coal	917,442	2,221,073	2,416,705
Oil	311,921	389,930	414,577
Gas	461,810	1,691,082	1,910,306
Multi fuel	36,607	127,249	152,483
Pumped storage	71,782	149,575	198,366
Conventional hydro	607,794	1,223,192	1,336,127
Nuclear	327,562	413,113	396,026
Wind onshore	2,463	780,508	1,250,519
Wind offshore		60,207	195,731
Concentrated solar	194	11,382	17,106
Solar PV	42	901,354	1,638,727
Biogas		22,063	29,911
Solid biofuel	9,978	71,077	90,837
Liquid biofuels		2,917	3,407
MSW and other waste	3,515	17,134	19,980
Biogas		22,063	29,911
Geothermal	5,623	12,831	14,478
Ocean / tidal	545	1,708	1,954
Other	847	2,024	2,024
Total	2,758,124	8,120,483	10,119,175

Source: StatPlan Power Predictor database, IEA, EIA, national sources

Table 2: comparison of electricity consumption data from IEA, EIA, and BDEW for the UK, in TWh

	Gross/ Net	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DUKES	Net	329	318	319	317	303	304	304	300	301	296	281	286
IEA	No inf.	338	326	326	324	311	311	311	307	308	303	287	293
EIA	Net	331	320	322	322	309	311	309	306	307	304	290	

The ratio of distributed transformer capacity (MVA) to total generating capacity (MW) has grown from 7 % in 1990 to 24 % in 2020 and is predicted to reach 32 % in 2030

ally, assigning weights for the numbers of primary and secondary substations.

4. The models

4.1. Estimation of central generation step-up (CGSU) and distributed generation step-up (DGSU) transformer capacity

The growth of distributed generation and renewables is changing the proportions of generation by central and distributed sources with an impact on the transformer population. In the 10th Edition of the StatPlan Transformer Report and in future editions, distributed generation (DGSU) is defined as generation fed into the grid at voltages under 36 kV and capacity under 10 MW, with transformer capacity under 10 MVA. With voltage and capacity higher than these, the feed-in is assigned to central generation (CGSU), often termed "utility generation." With this definition, the ratio of distributed transformer capacity (MVA) to total generating capacity (MW) has grown from 7 % in 1990 to 24 % in 2020 and is predicted to reach 32 % in 2030. The methodology for plotting the growth of DGSU involved two stages. Firstly, a database of generating capacity was required with a detailed analysis of the energy sources (see Table 1), and secondly, a model for the estimation of central and distributed generating transformer capacity.

4.2. Model for the estimation of central and distributed generating transformer capacity

A model has been created which starts with generating capacity in MW as classified in Table 1, and ends with two curves for each country, % DGSU distributed MVA capacity and % CGSU central MVA capacity plotted from 1990 to 2030, as illustrated in Table 3.

Each energy source is assigned a % share of DGSU and a % share of CGSU. The classification of energy sources as central or distributed is it not always straightforward. In most cases, the two percentages add up to 100 %, including a share of off-grid small installations. The early solar PV and wind installations were small, and their output was fed via a single MV line to a distribution network. Systems have grown in size, and today power is gathered in large installations, both on- and offshore power in a distributed MV (and recently HV) array and then exported via an HV or EHV export cable, the total combination of distributed and central power exceeding 100 %. (In this paper, MV is defined as a voltage from 1 < 36 kV, HV ≥ 36 kV < 345 kV, EHV ≥ 345 kV). The complexity is multiplying fast, especially for North Sea offshore wind power. The UK has 8 offshore wind clusters and has licensed independent grid operators. The Netherlands and Denmark are creating energy islands, with complete central installations equipped with HV/EHV substations, converter stations for AC (alternating current) to HVDC (high voltage direct current), and all the facilities of a land-based transmission grid linking multiple generators, exporting power to land. This underlines the need for a detailed analysis of the central / distributed energy equation.

Two conventional sources, hydrocarbon (diesel, HFO, LFO or coal, and gas engines and turbines) and hydro have historically had significant inputs to distribution networks, identified by MW or MVA capacity. For both, generators up to 10 MW are classified as distributed. The international convention for hydro classified as small hydropower (SHP) is defined as up to 10 MW, but some countries differ, in a few extreme cases up to 50 MW and others below 10 MW. We assigned a default position of 10 % of hydro as SHP / distributed, 80 % as central, and 10 % off-grid. The term "off-grid" refers to an independent generator not connected to a distribution grid, often a domestic household, farm, or small business establishment. Each country was assigned a different specific percentage if it differed from this in the UNIDO (United Nations Industrial Development Organisation) World Small Hydro Development Report.

The allocations for some renewables are less clear. Ocean / tidal power is mostly fed into distribution grids except for big tidal barrages, the largest being La Rance in France, operational for many years, and Lakantuka in Indonesia, soon to be operational. Both of these feed power into the transmission grid. Biomass and geothermal are mostly distributed, but some large plants exist and are classified as CGSU.

Wind and solar are the most complex for which to define the shares of distributed and central generation. Both of these have installations ranging from residential off-grid to utility size, and larger installations have both distributed and central generation components. Both wind turbines and solar PV are connected into MV (1 < 36 kV) or HV (≥ 36 kV < 345 kV) onshore or offshore arrays. While these have been MV so far, offshore arrays are now being built with 66 kV cables. The arrays are connected via a substation, either direct to a land-based distribution network or to a transmission network via a step-up substation, in the latter case, encompassing both distributed and central components. In all of these cases, % shares have been assigned for DGSU and CGSU.

The conversion from MW generating capacity to MVA transformer capacity involved 29 separate % allocations for individual categories for each country. Generating capacity was broken into two segments, Renewables, and Non-renewables, which include hydrocarbons and nuclear energy. Within the Renewables segment, 13 categories were identified, and the same for CGSU, and within Non-renewables, 2 categories for DGSU and 1 for CGSU, as listed below.

- **Renewables DGSU and Renewables CGSU** - separately for each, 13 categories (Hydro conventional, Pumped storage, Wind onshore, Wind offshore, Concentrated solar, Solar PV, Biomass, MSW (Municipal solid waste) and other waste, Liquid biofuels, Biogas, Geothermal, Ocean / Tidal, Other
- **Non-renewables DGSU** - Hydrocarbons in 2 categories: distributed gen-

Table 3. Estimation of central and distributed transformer capacity for wind and solar in the USA, 2020

		Capacity (MW)	% of total capacity requiring DGSU tx	DGSU tx MVA (MW*1.15)	% of total capacity requiring CGSU tx	CGSU tx MVA (MW*1.15*1.1)
Wind	Wind onshore	122,273	100 %	140,614	50 %	77,338
	Wind offshore	32	100 %	37	95 %	38
Solar	Concentrated solar	1,758	65 %	1,314	20 %	445
	Solar PV	73,814	50 %	42,443	50 %	46,687

eration by diesel gensets & microturbines; consumption by auxiliaries and local grids at large plants

- **Non-renewables CGSU** - Hydrocarbons and Nuclear in 1 category (large power plants)

Each of the Renewable categories was assigned a percentage of capacity fed into central or distributed networks, totalling 26 cells. For example, solar PV was assigned 65 % to DGSU and 20 % to CGSU, with the balance of 15 % off-grid and / or not being fed into the network with a step-up transformer. 100 % of onshore wind power is fed into a distribution array or network with DGSU transformers, and of that 50 % into a transmission grid. 100 % of offshore wind power is fed to an offshore substation, of which 95 % is to an export cable with CGSU transformers and then to a transmission grid onshore.

The conversion from MW generating capacity to MVA transformer capacity involved 29 separate % allocations for individual categories for each country

In the Non-renewable segment (hydrocarbons and nuclear), the larger quantity is generated by large power plants and fed into the transmission networks with CGSU transformers. A smaller amount is produced by small plants (coal, HFO, LFO, and diesel) and fed into the distribution networks with DGSU transformers.

Table 3 is an example of the separate tabulations for the Renewables categories of wind and solar. Tables containing all the above-mentioned categories have been compiled for each of the 184 countries. They record data annually from 1990 to 2030.

Figure 4. Phase-shifting large power transformers in Swissgrid's transmission grid (photo courtesy of SMIT Transformers)

There are large differences between countries and regions in the development of distributed generation, with the most rapid escalation in penetration taking place in Europe from 2000 to 2020

A similar set of tables was compiled for Non-renewables following the same method but with different percentages and ratios assigned. The tables are consolidated in the DGSU/CGSU database. The total capacity of GSU (generator step-up) transformers is split 20 % for distributed generation and 80 % for central generation, see Figure 5. This figure shows nicely how big change is presently ongoing in the power generation industry.

There are large differences between countries and regions in the development of distributed generation, with the most rapid escalation in penetration taking place in Europe from 2000 to 2020, with the introduction of renewables on a large scale (Figure 6).

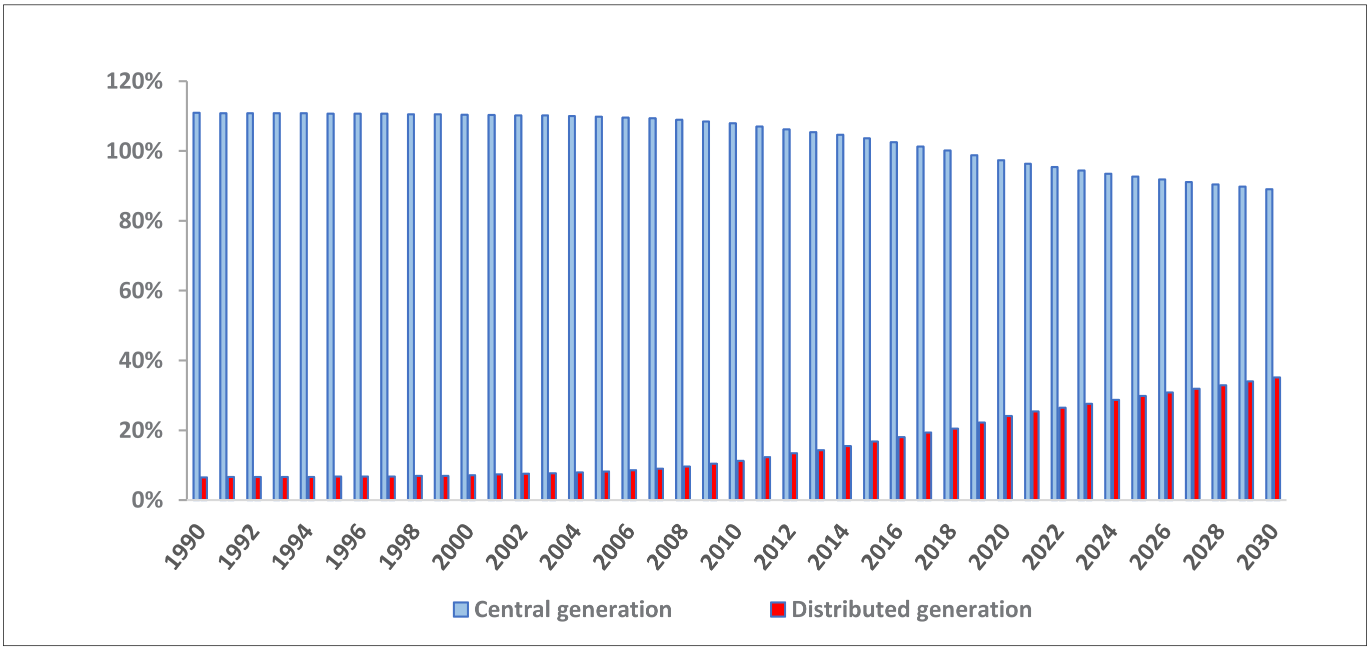

Figure 5. The global growth in distributed generation transformer capacity DGSU, 1990 to 2030

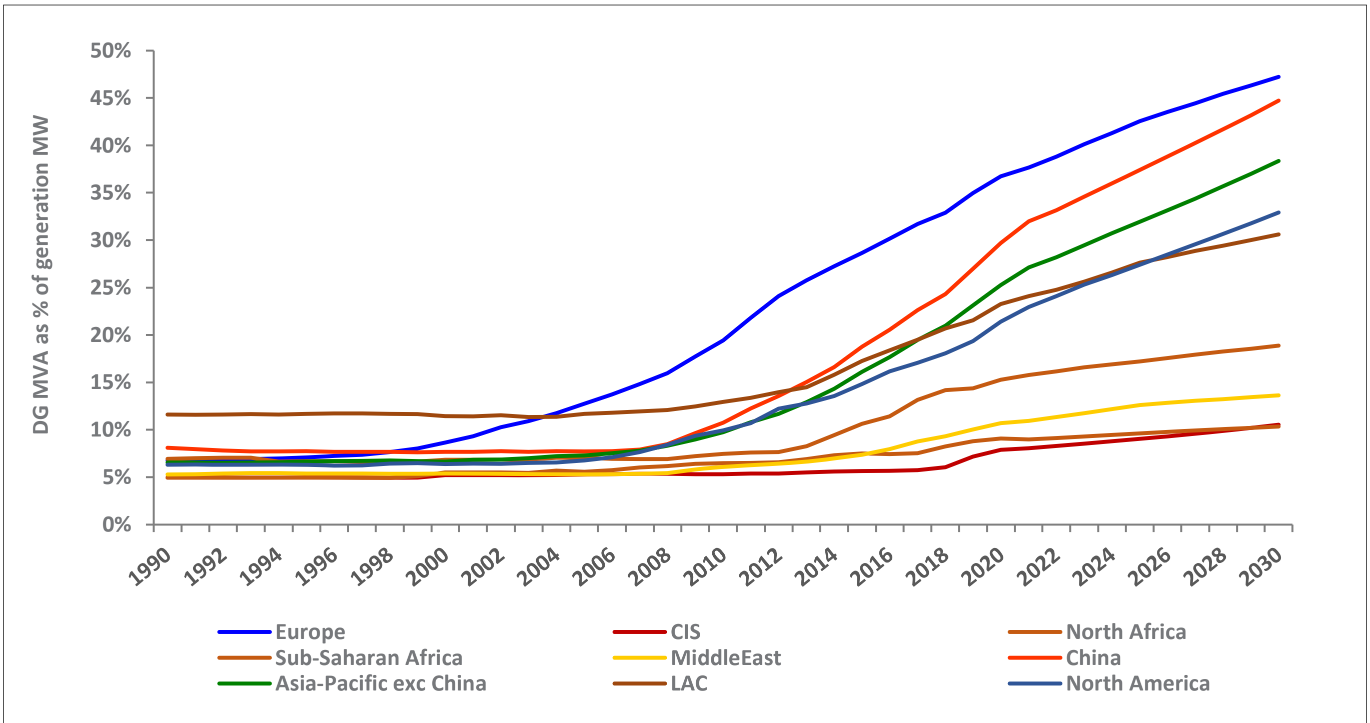

Figure 6. The growth in distributed generation transformer capacity DGSU, 1990 to 2030 analysed by region

4.3. The installed base of DT network transformers, MV and LV

Powergrid, the central Indian transmission grid, operates a network at 765 kV, 400 kV, 230/220 kV, feeding 132/110 kV and 66 kV sub-transmission networks owned by the states' transcos

The determination of the installed capacity of distribution transformers in the distribution grid was carried out in three stages. The following example is for India.

1. Total electricity consumption was recorded for the years 2011 to 2021 in five end-user groups; residential, commercial, industrial, transport, and agricultural in GWh. For brevity, we show only 2020 and 2021 here. The latest IEA total is for 2020. No consumption data is available for 2021, but the Indian Ministry of Power has published generation data for 2020 and 2021, and we have weighted IEA 2020 consumption to 2021 (Table 4).
2. The average power in MW of each user group is determined by dividing GWh *1,000 by 8,760 hours per year. In each user group, a different percentage of power is delivered via distribution transformers to the customer, the remaining being directly supplied by power transformers (Table 5).
3. Each user group was assigned an average load or utilisation factor, and the MW power was divided by the average load to give MVA installed capacity. Average loads ranged from < 20 % for residential to 35 % for commercial and 50 % for industrial (Table 6).

Table 4. Electricity consumption by end-user groups in India, GWh

Period	Residential	Commercial	Industrial	Transport	Agriculture	Public & other	All sectors
Annual totals: GWh							
2020	286,259	98,323	494,014	17,753	195,905	64,931	1,157,185
2021	309,045	106,150	533,338	19,166	211,499	70,099	1,249,297
% of total 2021	24.7 %	8.5 %	42.7 %	1.5 %	16.9 %	5.6 %	100.0 %

Table 5. Average generating capacity in MW providing electricity for each user group in India

MW	Residential	Commercial		Industrial		Transport		Agriculture		Public & other		All sectors
		total	via DT	total	via DT	total	via DT	total	via DT	total	via DT	via DT
	100 %		**98 %**		**85 %**		**30 %**		**98 %**		**98 %**	
2020	32,678	11,224	11,000	56,394	47,935	2,027	608	22,364	21,916	7,412	7,264	121,401
2021	35,279	12,118	11,875	60,883	51,751	2,188	656	24,144	23,661	8,002	7,842	131,065

Table 6. Installed DT (liquid and dry) capacity in MVA in India

MVA	Residential	Commercial via DT	Industrial via DT	Transport via DT	Agriculture via DT	Public & other via DT	All sectors via DT
Utilisation factor	**20 %**	**35 %**	**50 %**	**20 %**	**20 %**	**30 %**	
2020	163,390	31,428	95,870	3,040	109,582	24,213	427,522
2021	176,396	33,929	103,502	3,282	118,304	26,140	461,553

The transmission grids feed an estimated 85 % of power to the 1–35 kV distribution networks, and the balance of 15 % is supplied to industry or other entities at voltages of 36 kV and above

Some of the electricity passes through primary and secondary distribution substations in the utility distribution network before reaching the MV/LV distribution transformer and probably more in the industrial and commercial segments.

4.4. The Indian transmission and distribution systems

Powergrid, the central Indian transmission grid, operates a network at 765 kV, 400 kV, 230/220 kV, feeding 132/110 kV and 66 kV sub-transmission networks owned by the states' transcos. The topology of Indian distribution networks varies a lot because of the huge size of the country and the many different distribution companies. Substations of 66 kV are variously described as sub-transmission or primary distribution. They are rated at 20–100 MVA. The current is stepped down from 132 kV or 66 kV to primary 33 kV distribution or to 11 kV secondary distribution lines. Substations of 33 kV typically have a total capacity of 20–60 MVA, and 11 kV substations have a total capacity of up to 20 MVA if coming from a 66 kV grid and lower if being fed from a 33 kV grid. Secondary distribution takes place mainly at 11 kV. Other secondary voltages in operation are 22 kV and at a local level of 6.6 kV, 3.3 kV, and 2.2 kV. The 11 kV substations are the most common and mostly step current down to 400/230 V. The 11 kV feeders may only be 1–3 km long in the cities but range up to more than 20 km in rural areas. Residential customers are supplied either with 400 V three-phase or 230 V single-phase systems, with are usually a few hundred meters long at maximum to avoid overly high voltage drops and losses.

Large industrial customers may be connected directly at 33 kV or above in some cases. Other large customers (industrial, commercial or institutional) are connected directly to the 11 kV grid if their peak load exceeds a certain value. A 100 kVA is a typical limit (used, for example, in Delhi and Gujarat), while other states set the limit at 75 kVA (Madhya Pradesh), 63 kVA (Uttar Pradesh), or 50 kVA (Rajasthan).

4.5. Calibration of final MVA capacity by the number of primary and secondary substations

The 449 GW of Indian generating capacity in 2020 consisted of 374 GW utility and 75 GW non-utility or captive generation and requiring a total of 3,368 GVA, consisting of 451 GVA of central GSU capacity and 94 GVA of distributed GSU capacity, 2,135 GVA of PT capacity and 688 GVA of DT capacity. The Indian Ministry of Power published a total of 2,960 GVA in the utility system in April 2021.

4.6. The installed base of PT network transformers

The transmission grids feed an estimated 85 % of power to the 1–35 kV distribution networks, and the balance of 15 % is supplied to industry or other entities at voltages of 36 kV and above, and it is stepped down by transformers owned by the users. The transmission networks have a higher range of voltage, from 66 kV up to 345 kV, 380 kV, 400 kV, 500 kV, 750 kV, and even higher for the DC networks. On its journey to the consumer, the electricity passes through a step-down power transformer an average of 3.3 times in the transmission grid and 1.7 times through a distribution transformer in the distribution grid, with higher capacity per transformer in transmission than distribution, resulting in higher total transformer capacity in the transmission grid than in distribution. These ratios have been derived from the database accompanying the StatPlan Transformer Report, which lists transformer capacity by region, country, and system segment. The transformer capacity has been calculated for each country by the methods outlined in this report; for DGSU and CGSU as described in paragraph 4.2, Network DTs as in paragraph 4.3, and network PTs as in paragraph 4.6. The national totals in each segment have been added together to obtain the world totals and divided by MW capacity to achieve the ratios shown in Table 7.

Data about the transformer capacity in transmission systems is available from utilities and national sources for most countries. The totals of all HV transmission power transformers are estimated by applying a multiple of 1.15 to these utility figures.

4.7. Forecast model

The demand forecast model has two stages.

1. Sales in the base year are disaggregated into the cost components; materials, labour, and overhead / oth-

Table 7. World ratios of transformer capacity to generating capacity by transformer segment

Generation	Ratios of transformer capacity to generating capacity				
Capacity	CGSU	Network PT	DGSU	Network DT	Total
GW	GVA	GVA	GVA	GVA	GVA
7,424	0.97	3.32	0.25	1.72	6.27

Source: StatPlan Transformer Report Ed. 10, 2022

Note that the ratio for the total GSU transformer capacity in MVA adds up to 1.22 x the general total generation capacity in MW.

The forecasting model has shown that it can reflect increases in market value due to rising prices of materials and other inputs, even when consumption is stagnant or in decline

ers. Demand for each component is forecast separately at constant values based on the power consumption trend. Growth (or decline) from 2019 to 2022 has been interrupted in each country by the Covid pandemic to a different extent. Actual 2020 and 2021 figures are entered. A constant growth from 2021 to 2027 is estimated on a historical growth basis, using data from 2011 to 2019, before the Covid's impact.

2. Constant values of individual cost components are projected to nominal market values based on expected material price forecasts, inflation, and productivity. Six components have been identified for transformer manufacturing costs.
   1. Transformer oil
   2. Copper
   3. Steel
   4. CRGO
   5. Labour
   6. Overhead / other costs

The materials (transformer oil, copper, steel, CRGO) are weighted each year by forecasts of future prices in each year of the forecast period, using data from T&D Transformers Commodities Indices [3], the biennial World Bank Commodities Market Outlook [5], Trading Economics [5], IMF (International Monetary Fund), international industry reports and personal assessments from industry executives. These forecasts are applied to the constant growth figures for each year with a standard table format. The constant growth for labour, overhead, and other costs is modified each year by inflation and productivity gains.

The markets in each country were sized in several ways, dependent on the data available. Wherever possible, they were calculated as the sum of transformer production in the country plus imports minus exports. In some cases, countries publish precise production data, and in others, we have summed the output of individual manufacturers, either with published data or best estimates. Import and export data was averaged over five years. In other cases, it was impossible to obtain production data, and in these cases, we estimated demand as the sum of new installations of capacity plus replacements based on installations in the year of installation.

5. Conclusion

The consumption-based methodologies used to determine transformer capacity have demonstrated a sensitivity to increases or declines in consumption superior to the outcomes based on installed generating capacity. This is augmented by a detailed analysis of the structure of the distribution networks of each country, which is missing in the generating capacity method. In addition, the forecasting model has shown that it can reflect increases in market value due to rising prices of materials and other inputs, even when consumption is stagnant or in decline.

Bibliography

[1] StatPlan transformer reports: https://www.statplanenergy.com/team/

[2] IEA: https://www.iea.org/data-and-statistics/data-product/electricity-information

[3] T&D Transformers Commodities Indices for GOES, Mineral Oil, Paper, Steel: https://www.tdeurope.eu/publicationss/technical-information.html

[4] US producer price index for transformers: https://fred.stlouisfed.org/series/PCU3353113353111

[5] Copper and Aluminium – World Bank Commodity Markets Outlook: Commodity Markets Outlook -- October 2022 (worldbank.org)

[6] Copper and Aluminium - Commodity Forecast 2022/2023: https://tradingeconomics.com/forecast/commodity

PEER REVIEWED

Authors

Euan Blauvelt graduated with an MA from Cambridge University and started his career in market research, first in London, and he then spent 12 years in Southeast and East Asia, working for industry and governments, and finally as Deputy Chairman of the Survey Research Group. Returning to the UK, he was a partner in ABS Energy Research, with a wide range of clients in the power, gas, and water sectors. Since 2000 as the founder of StatPlan Energy Research, he has specialised in the electrical sector and has created global databases and forecasts for electricity supply, T&D, the transformer, energy metering, and cable markets.

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 Head of Business Development and Head of Operational Excellence of the SGB-SMIT Group, Regensburg, Germany. For the last two years, Martin has run his own company, "SISTEMA Consulting."