Generator step-up transformers

Market development from oil shock to non-fossil renewable era

1. Background

The development of global power generating capacity since the first „oil shock" in the early 1970s has evolved dramatically and has had a fundamental impact on the production of generator step-up (GSU) transformers. With relatively cheap oil prices in the order of $10 per barrel, this and coal was the fuel of choice for most developed country electricity utility companies. The almost overnight tripling of the price of oil to the unimaginable levels of $30 per barrel forced a major rethink and re-assessment of the future plans. Security and diversity of energy fuel supply became the order of the day for those countries with an unhealthy reliance on hitherto cheap imported fossil fuel. Germany and the UK with indigenous plentiful supplies of brown coal and black coal, respectively, developed these resources, as did the USA with plentiful coal and oil; France and Japan with no natural resources installed base-load nuclear power – as did many of the major power producers around the world.

Most of the capacity shown in Table 1 was installed in the decade 1975 to 1985 and most of the individual reactors were in the order of 300 MWe each.

Similarly, the conventional fossil fuelled capacity increased dramatically, with over 450,000 MW being installed during the same period of time; and as technology improved, so did the average size of these units – from the 20 – 30 MW that were the norm in the 1950s, through the 100 MW barrier in the 1960s to coal fired units equal in size to their nuclear counterparts by the 1970s and 1980s.

The development in global installed capacity is shown in Table 2.

In the decade between 1975 and 1985, over 771,000 MW were installed, 646,000 MW

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in the following decade, over 1,000 GW during 1995 and 2005 and over 2,000 GW from 2005 to 2015.

During the last three decades of the last century the trend was to build large nuclear and fossil fuelled centralised power stations with ever increasing capacity and ever increasing size of unit.

The installed capacity by type in 1975 is shown in Table 3, and for comparison the situation in 2015 is also shown in Table 4.

The most obvious change over time has been the global increase in renewable capacity from 0.27 % in 1975 to 7.74 % in 2015; nuclear has remained static whilst hydro capacity has reduced by 5 % and thermal capacity has reduced by 2 %. However, the regional variations are much greater than the global picture. Western Europe has increased renewable capacity from 0.38 % to 21.55 % over the period, and reduced conventional thermal capacity by 15 % and hydro by 10 %. Similar trends can by observed in other regions.

2. Impact of capacity changes on GSU transformers

So what exactly has been the impact of these trends on GSU transformers over the period 1975 to 2015?

The undisputable fact is that the number of GSU transformers installed has increased enormously - we estimate by a factor of 16 over the period 1975 to 2015. Clearly also the average size of the GSU transformers needed has decreased from an overall average size of 44 MVA in 1975 down to 7.5 MVA in 2015.

The breakdown of the number of units installed by size for the period 1975 to 1985 and comparison figures for the period 2005 to 2015 are shown in Tables 6 and 7.

The trend is clear – in every region the average size of GSU has decreased over time. The factors driving this trend are separate but linked. Firstly, in most regions of the world there is a trend away from large centralised generating stations towards more decentralised units. The reasons for this are complex, but have roots in the fact that many countries have liberalised their electricity generating monopolies, which has encouraged competition in the field of electricity generation; and that grid and load control technology has improved to allow for a more complex and diverse generating network.

It also has to be acknowledged that the global trend towards renewable generating facilities and away from fossil fuel generation has hastened this trend. The large monolithic coal, oil and nuclear generating stations are being replaced with more environmentally acceptable alternatives. This inevitably means many more but smaller generating units. One 1970s 1000 MW generating station may now be

Multiplication of the price of oil forced a major rethink and re-assessment of the future plans

Table 1. Installed nuclear generating capacity worldwide

Country	Number of operated reactors	Capacity (MWe)	%-share of total usage	Generated (GWh)
United States	100	100,351	19.7 %	804,873
France	58	63,130	72.3 %	386,453
Japan	43	40,290	2.2 %	17,537
China	36	31,384	3.6 %	197,829
Russia	36	26,528	17.1 %	184,054
Republic of Korea	25	23,077	30.3 %	154,307
Canada	19	13,554	15.6 %	95,650
Ukraine	15	13,107	52.3 %	76,078
Germany	8	10,799	13.1 %	80,070
Sweden	10	9,740	40.0 %	60,647
United Kingdom	15	8,918	20.4 %	65,149
Spain	7	7,121	21.4 %	56,102
India	22	6,240	3.4 %	35,007
Belgium	7	5,913	51.7 %	41,430
Taiwan	6	5,052	13.7 %	30,461
Czech Republic	6	3,930	29.4 %	22,730
Switzerland	5	3,333	34.4 %	20,303
Finland	4	2,764	33.7 %	22,280
Bulgaria	2	1,926	35.0 %	15,083
Hungary	4	1,889	51.3 %	15,183
Others	23	13,513		94,990
World total	**451**	**392,559**	**10.90 %**	**2,476,217**

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replaced with five hundred 2 MW wind turbines.

This has had the effect of changing the manufacturing base and competitive envi-

Table 2. Global installed capacity by region 1975 to 2015 MW

Region	1975	1985	1995	2005	2015
Western Europe	313,925	490,961	553,805	656,300	910,656
Eastern Europe & Federal Soviet Union	282,318	425,248	449,156	462,501	513,806
Africa	32,288	61,064	90,584	110,645	164,018
Middle East	16,688	61,607	105,403	183,499	336,207
Indian Sub-continent	26,544	58,424	113,507	171,325	361,429
Asia	186,614	305,957	559,153	1,010,537	2,139,065
South America & Carribean	54,536	108,932	154,221	220,576	301,508
North America	616,451	774,897	899,494	1,130,744	1,294,056
Oceania	26,858	40,189	48,689	60,363	79,466
World total	**1,556,222**	**2,327,279**	**2,974,012**	**4,006,489**	**6,100,210**

Table 3. Global installed capacity by type 1975

Region	Thermal	Renew	Nuclear	Hydro	Total 1975
Western Europe	61.12 %	0.38 %	9.09 %	29.41 %	100.00 %
Eastern Europe & Federal Soviet Union	72.48 %	0.00 %	1.15 %	26.37 %	100.00 %
Africa	69.97 %	0.00 %	0.00 %	30.03 %	100.00 %
Middle East	81.42 %	0.06 %	0.00 %	18.52 %	100.00 %
Indian Sub-continent	60.96 %	0.00 %	2.56 %	36.48 %	100.00 %
Asia	71.78 %	0.25 %	8.05 %	19.92 %	100.00 %
South America & Carribean	46.67 %	2.00 %	0.52 %	50.80 %	100.00 %
North America	72.16 %	0.22 %	8.62 %	19.01 %	100.00 %
Oceania	66.18 %	0.50 %	0.00 %	33.32 %	100.00 %
World total	**68.81 %**	**0.27 %**	**6.48 %**	**24.43 %**	**100.00 %**

ronment with respect to the manufacture of GSU transformers. In the 1970s, there were only a handful of companies worldwide that were trusted to manufacture the super critical GSU transformers with capa-

The number of GSU transformers installed has increased enormously – by a factor of 16 over the period 1975 to 2015

Table 4. Global installed capacity by type 2015

Region	Thermal	Renew	Nuclear	Hydro	Total 2015
Western Europe	46.33 %	21.55 %	12.48 %	19.64 %	100.00 %
E Europe & FSU	65.81 %	2.89 %	10.77 %	20.53 %	100.00 %
Africa	80.02 %	1.22 %	1.13 %	17.62 %	100.00 %
Middle East	87.40 %	1.17 %	0.27 %	11.15 %	100.00 %
Indian Sub Con	75.61 %	7.20 %	1.84 %	15.34 %	100.00 %
Asia	70.59 %	5.87 %	4.24 %	19.30 %	100.00 %
S America & Caribbean	48.14 %	1.50 %	0.99 %	49.37 %	100.00 %
North America	69.06 %	6.97 %	9.06 %	14.90 %	100.00 %
Oceania	71.14 %	10.76 %	0.00 %	18.10 %	100.00 %
World Total	**66.62 %**	**7.74 %**	**6.38 %**	**19.26 %**	**100.00 %**

Table 5. Number of GSU units by region 1975 to 2015

Region	1975 to 1985	1985 to 1995	1995 to 2005	2005 to 2015
Western Europe	3,381	5,059	27,443	70,334
E Europe & FSU	2,061	287	1,936	12,950
Africa	761	344	436	3,512
Middle East	331	730	2,053	10,104
Indian Sub Con	804	1,075	4,518	15,817
Asia	2,766	5,282	11,593	110,554
S America & Caribbean	4,098	2,543	5,236	4,652
North America	3,091	10,763	7,966	48,020
Oceania	181	570	901	5,099
World Total	**17,474**	**26,652**	**62,082**	**281,043**

Table 6. Breakdown of GSU units by size by region 1975 to 1985

Region	Over 100	25 to 100	10 to 25	Less than 10	Total
Western Europe	16.37 %	33.73 %	19.96 %	29.94 %	100.00 %
Eastern Europe & Federal Soviet Union	24.77 %	30.05 %	45.08 %	0.10 %	100.00 %
Africa	18.14 %	12.43 %	49.71 %	19.72 %	100.00 %
Middle East	49.67 %	36.32 %	9.08 %	4.94 %	100.00 %
Indian Sub-continent	17.90 %	8.21 %	57.47 %	16.42 %	100.00 %
Asia	13.42 %	34.03 %	21.02 %	31.53 %	100.00 %
South America & Carribean	2.22 %	27.27 %	40.90 %	29.61 %	100.00 %
North America	15.14 %	26.37 %	17.58 %	40.90 %	100.00 %
Oceania	23.00 %	45.06 %	19.31 %	12.63 %	100.00 %
World total	**13.02 %**	**28.46 %**	**31.43 %**	**27.09 %**	**100.00 %**

Table 7. Breakdown of GSU units by size by region 2005 to 2015

Region	Over 100	25 to 100	10 to 25	Less than 10	Total
Western Europe	2.18 %	8.72 %	12.87 %	76.22 %	100.00 %
Eastern Europe & Federal Soviet Union	7.12 %	27.85 %	15.96 %	49.06 %	100.00 %
Africa	9.97 %	39.86 %	27.27 %	22.89 %	100.00 %
Middle East	10.58 %	42.30 %	28.55 %	18.57 %	100.00 %
Indian Sub-continent	4.70 %	18.43 %	11.56 %	65.31 %	100.00 %
Asia	3.69 %	14.57 %	29.36 %	52.37 %	100.00 %
South America & Carribean	8.32 %	33.28 %	35.04 %	23.36 %	100.00 %
North America	6.79 %	27.07 %	12.46 %	53.68 %	100.00 %
Oceania	8.87 %	35.48 %	6.39 %	49.26 %	100.00 %
World total	**4.56 %**	**18.07 %**	**20.35 %**	**57.02 %**	**100.00 %**

The average size of GSU transformers has decreased from an overall average size of 44 MVA in 1975 down to 7.5 MVA in 2015

cities exceeding 300 MVA. Although many of the trusted manufacturers were affiliated with the power station developers, this was not favouritism or nepotism, but harsh financial reality. If a GSU transformer failed in the field, the entire output of that generating unit was lost for the two years that it took to order and install a replacement transformer. This was something that the banks/governments that were financing the power station took a very dim view of, and was to be avoided at all costs.

Now in the 2015 era, building a GSU transformer with a capacity of less than 10 MVA is not so technologically challenging, and in most cases on an individual basis is not so super-critical in the event of an individual failure. Therefore, what was the domain of the few is now the domain of the many.

The ability to design, build and supply the very largest sizes of GSU transformer is an ability for which there is very definitely an on-going demand, and the manufacturers with that capability will continue to reserve that sector to themselves; however, it is numerically a very much smaller sector with over half of the GSU's installed now being less than 10 MVA.

Author

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