SMALL POWER PLANTS CONNECTED WITH MV-NETWORKS

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SUMMARY

Small power plants (SPPs) affect utilities network expenses. Some of them may act as Independent Power Producers (IPPs) on a free Austrian electricity market in future. Power inputs in MV-lines make premature network investments necessary. Operating costs have also to be considered.

The following results due to network investment affected by SPP power input in MV-systems supported the tariff-expert-team of the Association of Austrian Utilities discussing the new tariff model in spring 1997.

Network planning criteria due to SPP power input in MV-networks:

1. SPPs may improve short circuit power in MV-networks.
2. SPPs do not affect line losses in a remarkable way.
3. Power inputs of not more than 50 % of the minimum load of the line do not affect the supply situation. This power input may be generated by a singular or a number of SPPs. However, minimum load can be neglectable in many cases.
4. If the power input is more than 50 % of minimum load, for every MW generated the supplyable load is reduced by 2 MW.
5. An input of more than 50 % of the maximum supplyable load without power input is impossible.
6. The reduction of the maximum supplyable load as a result of power input is valid for all galvanically connected lines.

1 TIWAG SUPPLIES THE REGION OF TYROL

Tyrol, in the western part of Austria, is one of the most beautiful landscapes in the Eastern Alps. Within its 12,648 km^2 are 630,000 inhabitants in 279 communities. Tyrol is one of the 9 federal states of Austria and is famous for its summer and winter tourism activities. Places like Kitzbühel, St. Anton/Arlberg, Ischgl or Innsbruck are known all over the world. Tyrol is proud of its sporting traditions. The Olympic Winter Games of 1964 and 1976 were held here. The world championships of alpine skiing will be staged in St. Anton/Arlberg in the year 2001.

Tyrolean industry has a world-wide trading tradition. World wide organisations such as Swarovski, producing glass products; Biochemie Kundl GesmbH, famous for its invention of oral penicillin resulting in two nobel prize awards for biochemistry; Planseewerke, with its developments on metallurgy and Jenbacher Werke AG with its worldwide trading of diesel and gas co-generation plants, compressors and railway equipment.

As a result of the current negotiations due to the future regulation of Austrian electricity market, TIWAG will have single buyer status. Moreover the TIWAG group is owner of the gas company TIGAS, the telecom-service-provider TIKOM and the shipping company Achenseeschiffahrt GesmbH.

The main tasks of TIWAG as future single buyer will be

- to operate its interconnected 220 (380)-kV system as member of UCPTE;
- to produce electrical energy with its own power plants with an installed power of approx. 1500 MW and
- to supply customers over its distribution network.

2 SYSTEM USERS HAVE TO PAY THE COSTS BY FAIR MEANS

Unbundling of production, transport and distribution is one major point of the deregulation of European electricity market. In times of rising competition, it is TIWAG's crucial goal to supply the best quality conditions for the price our customers pay. To maintain a high quality means a lot of annual network investments for each utility. To meet these costs, producers and customers have to pay for the use of system and services.

SPPs have a special position in the current tariff discussion. These power plants may be water power plants, photovoltaic power plants, small co-generation plants or wind power plants with outputs of up to 10 MW. Frequently, the output of these SPPs is varyiable and does not correlate with the load-profile of the line connected. In particular, the use of small co-generation plants is usually directed by thermal demand. Electrical energy may be considered as waste product. If there is no demand for thermal energy, then co-generation plants cannot be operated cost effective in general.

Usually SPPs with an output of up to 100 kW are connected with the LV-network. Larger SPPs are usually connected with the MV-network. If in particular the generation exceeds the load of the line at minimum load conditions, MV-lines may feed back the HV-lines.

Up to now in Austria there have not been any existing tariffs that would be able to meet the costs of system operators due to the use by power plants.
The share of the transporting-function of singular parts of a network due to a certain power input or output may be time varyable corresponding with the local and temporary characteristics of load, production, circuit stage, etc. ... . Therefore every customer or producer takes part at the whole distribution system.

The current tariff discussion, primarily rises the question of the impact of SPPs to network investment as one origin of systems costs. The idea of the new model is to split up the costs valid for all participants by fair means and transparent conditions for system and services.

3 QUANTIFICATION OF THE TOPIC

SPPs are still attractive for long-term investment. The installed capacity of SPPs in Austria is approx. 700 MW corresponding to approx. 4,5 % of the whole generating capacity. The number of the units is still rising. Figure 1 gives an overview of the current situation.

TIWAG also faces a continuing rise in the number of SPPs. Waterpower is still the favorite way of production. However, co-generation plants are more and more common. Tyrol, situated in an alpine region, it has its waterpower-resources at the end of mountain-valleys. Usually the points of connection of power plants are situated at the end of MV-lines. Therefore it has always been a particular interest of TIWAG to investigate the impacts of SPPs to MV-networks.

The Tyrolean situation of 1996 is shown in fig. 2.

During the last few years the nomimal power of the units has been rising. Some of them needed a seperate 30-kV-feeder to a transformer station 110/30 kV. It has to be assumed, that this trend will continue under the influence of the deregulation of electricity market in future.

4 WE HAVE TO DIFFER BETWEEN SPPS CONNECTED WITH HV- OR MV-NETWORK

In general there are no defined tolerances for operating voltages of from 110 kV up to 380 kV. The only exceptions are at transfer-points between interconnected partners. In this case the limits are defined in private contracts. Large power plants, transformers with variable ratios, etc. ... and meshing the lines help to stabilize the voltage of these networks. However, ratios of HV/MV-transformers and voltage tolerances of MV-level may affect operating voltage at HV-level. MV- and LV-networks however, are voltage controlled. Operating voltages are well defined by IEC 38 and EN 50160 with narrow bands of tolerances. Compounded HV/MV-transformers usually manage the voltage control of MV-networks by variable ratios to a certain extent. However, MV/LV transformers in general have constant ratios. Voltage tolerances valid for LV-lines immediately affect voltage limits of MV-lines.

In rural areas radial networks are the common way to supply the area. High short-circuit impedances are one of the major disadvantages. Therefore SPPs are not able to stabilize operating voltage. However, utilities have the duty to supply their customers as savely as possible. Flexible operation needs circuits not affected by power stations. Power input-conditions have to be checked for all regular circuit states.

5 ACCESS CONDITIONS

If an SPP wants to use a network, the first step is to investigate the access conditions for this power plant and the given line. This is necessary to guaranty the quality of supply for the customers now and in future.This supply quality is strictly defined by EN 50160 for any point in the network considered. Moreover, due to the affect of power plants to quality of supply there is also a regulation existing in Austria: „Empfehlungen für die Beurteilung von Netzrückwirkungen“. It is issued by the Association of Austrian Utilities.

To secure the quality of supply due to SPPs means to prevent voltage fluctuation (flicker) caused by fast changes in the operating conditions of the generator or turbine. If these changes are rare, voltage fluctuation is allowed up to 2 % of U_N. Generators connected over power converters with the network will also have to meet the criteria for harmonics. It also means that the utility has to keep the power in reserve because the SPP-operators cannot guaranty the security of input.

With respect to the rising sensitivity of customers electronic systems it is of great importance to keep up the limits valid for voltage fluctuation and harmonics in the future as well.

6 LINE-MODELLING

The question of unbundling is a product of ecological consideration. However, due to technical reasons it is basically advisable to investigate network and generation as one technical system with vice versa effects. Under the consideration of network needs, planning of power plants raises a lot of very complex questions. The system-paramaters can be numerous. They mainly depend on the type of power plant, its generation characteristics and kind of operation as well as the type of the line and its load profile.

General rules can only be calculated by a line model typical for supply situations. However, projects have to be considered individually.

Our model used is typical for MV-situations of utilities with mainly rural supply characterstics. Depending on the cases considered the line paramaters differ (please look at the individual notes in the figures).

7 CAN WE RENOUNCE THE REACTIVE LOAD GENERATED BY SPPS?

MV-power producers are normally convinced that the reactive load generated is not necessary to support the reactive household load of the MV-network. The more cables we have in our MV-network the less reactive power should be generated by SPPs, they argue. The benefit would be to rise the active power output of the generator. Currently TIWAG's regulations say, that every IPP has to produce 50 % reactive power at minimum and each time corresponding to a power factor cos φ = 0,9. Figure 4 shows the demand of reactive power of the model-line depending on the load conditions of transformer stations, consumer power factor cos φ and the share of cable-length.

Results:
The result is that the line's reactive power demand is far more dependent on the consumer load than on the reactive power generated by MV-cables. Therefore it is a disadvantage for the utility to renounce the reactive power generation of SPPs.

8 DO SPPS REDUCE THE SHORT CIRCUIT IMPEDANCE?

It is commonly known that a small short circuit impedance reduces negative effects of flicker in MV-networks. Therefore every measure to reduce this impedance is an advantage for the utility.

Each generator connected with the network basically reduces the short circuit impedance. However, the degree of improvement always depends on the line's impedance and the short circuit characteristics of the generator.

Figure 5 shows four typical short-circuit-situations for radial operated networks.
If the SPP is in the first third of the line, short-circuit-power rises appr. 3%, if it is in the second third it rises approx. 4 % and if it is at the line end it rises approx. 5 % per MVA nominal output of the generator.

Results:
It can be concluded that the short circuit power of the network rises in general with the sum of the nominal power of the IPP's connected. However, it has to be noted that this advantage is reduced dramatically by the problems of voltage stabilization.

It has to be remarked that this improvement of MV-short-circuit-power usually does not require any reinforcements of equipment.

9 DO SPPS REDUCE LINE LOSSES?

Losses of MV-lines are typically ohmic. They mainly depend on the load and the line material. Every SPP power input affects load flow and therefore loss characteristics.

Results:
Assuming a homogene distribution of transformer stations with same load characteristics at the end of a line a generator reduces losses if the input is not more than 50 % of the current load. If the input is higher than the load losses rise (figures 6 and 6A). Therefore the input of a small power unit may rise or reduce line losses. Operational reality of radial networks proves that the minimum of losses cannot be reached under normal conditions because load and input do not usually correspond.

10 CAN SPPS SUPPORT VOLTAGE STABILIZATION?

HV/MV transformers usually control operating voltage of the MV-busbar corresponding to the load of the network supplied. It is also possible to compensate HV-fluctuations. However, it is not possible to compensate MV-voltage-changes in the network which consequently affects customers supplied on the MV- or LV-level.

The most important criteria for voltage stabilization is the load characteristic of the line. For our further investigations we have to know the annual maximum and minimum load. Figure 7 shows load characteristics typical for TIWAG supply areas.

In particular, lines supplying areas with low population density and weak industry infrastrukture and/or strong winter tourism have an extreme relation between the maximum an minimum load (fig. 7, lines 1, 2, 3). The share of minimum load is usually far less than 10 %. Lines supplying rural regions with high population density and permanent industry (fig. 7, lines 4, 5, 6, 7) may reach in singular cases shares of minimum load of approx. 12 %. The vast majority of the SPPs is connected with lines of the type 1, 2 and 3.

Comparing TIWAG with other utilities it can be seen that these minimum load conditions can be fewer still.

10.1 Consideration of a singular line with power input

Assuming a constant operating voltage of U = 25,5 kV at the busbar of the HV/MV-substation and assuming medium ratio for all transformers usable for voltages from 23,8 kV up to 25,5 kV the load of our model-line can be ultimately 12,4 MW. The voltage at line end will be 23,8 kV (fig. 8, curve 1).
Assuming a relatively high share of minimum load of 1,8 MW and a voltage at the busbar of 25,5 kV we will find

25,3 kV at line end (fig. 8, curve 2). A power input at line end of not more than 0,8 MW raises the voltage at the busbar of the power plant up to the maximum level allowed 25,5 kV (fig. 8, curve 3). The maximum supplyable load is still only 12,4 MW because the operator of the power plant cannot guaranty the steady power input.

If we rise power input up to 4 MW, operation voltage at the busbar of the substaion has to be reduced to 24,6 kV. Otherwise the voltage at line end would be higher than the allowable maximum (fig. 8, curve 4). This voltage at the busbar allows only 5,6 MW to be supplied because also in this case the operator of the power plant cannot guaranty the steady power input (fig. 8, curve 5).

Results:
To sum up we can say that the power input of SPPs need a share of voltage band (fig. 9). Therefore utility may only be able to supply a part of the load needed by the customers. Reinforcements of the line need to be invested some years earlier.

1. Power inputs of not more than 50 % of the minimum load of the line do not affect the supply situation. This power input may be generated by one or more units. Hower, minimum load can be neglectable in many cases.
2. If the power input is more than 50 % of minimum load every MW generated reduces the supplyable load by 2 MW.
3. An input of more than 50 % of the maximum load supplyable without power input is impossible.

10.2 Consideration of a busbar supplying several lines

In reality the line in question is connected with a substation busbar supplying more than one line (fig. 3). The other lines can also be connected with SPPs.

Results:
1. The reduction of the maximum supplyable load as a result of power input is valid for all galvanically connected lines.
2. Different operating voltages of double busbar arrangement may prevent busbar-coupling.

10.3 Does power input affect network investment?

Inputs of SPPs need a share of voltage band. As already mentioned above earlier network investment may be necessary.

A good example typical of MV-power-input situations makes the possible investment clearer.

The model-line assumed has the following parameters:
- part 1: l = 5000 m, 60 % AWAL 105, 40 % EA 300 VPE;
- part 2: l = 10.000 m, 60 % Ald 70, 40 % EA 95 VPE;
- medium transformation ratio usable for 23,8 kV - 25,5 kV;
- maximum load: 10,5 MW, minimum load: 2,1 MW, trend of peak load 2 % p.a.;
- power input at line end: P = 3 MW, cos φ = 0,9;
- interest rate: i = 5 %;

Due to power growth first of all the utility has to reinforce the weak parts of the line. It is assumed that the reinforcement has the same percentage of cabling as the genuine situation. After approx. 20 years all weak parts of the line are inforced. Further load increase makes a second line or a further substation necessary.

Results:
Considering power input as mentioned above, network investment has to be done far earlier. The costs may be higher than 70 % than without power input.

10.4 Do SPPs affect network operation costs?

Usually SPPs are operated unmanned. Operating staff, who should be in contact with utility personnel whenever needed, are not attainable in reality very often. Only in a few cases SPPs have telemonitoring or are remote controlled by the operation center of the utility.

Results:
In case the operators of SPPs are not reachable, staff of TIWAG have to switch off the power input when working conditions make it necessary. This increases mainly travelling expenses and may affect interruption times of customers.

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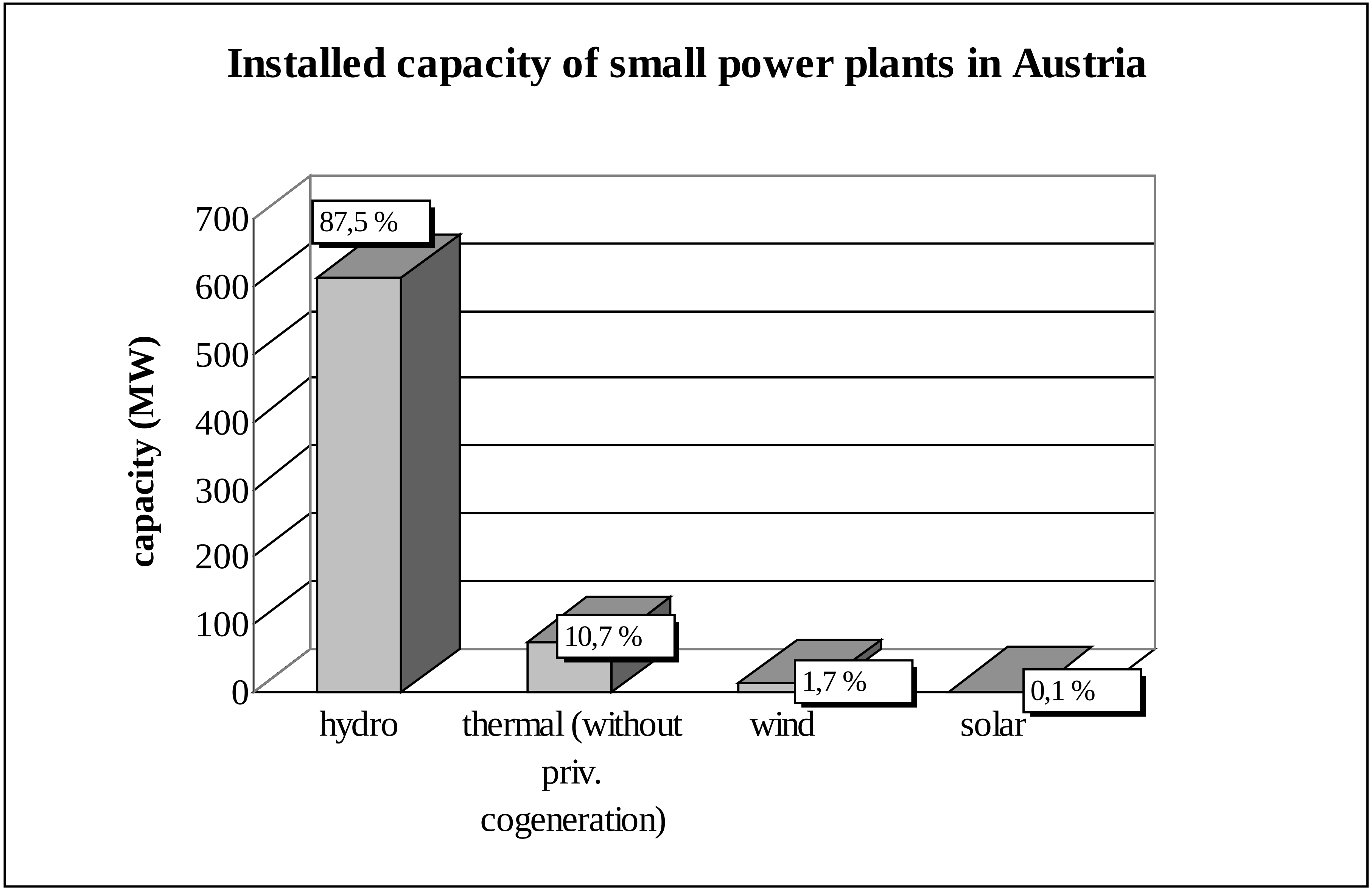

Figure 1: In 1996 the sum of the installed capacity of small power plants (without priv. Cogeneration) was approx 700 MW
Hydro power is the major power source

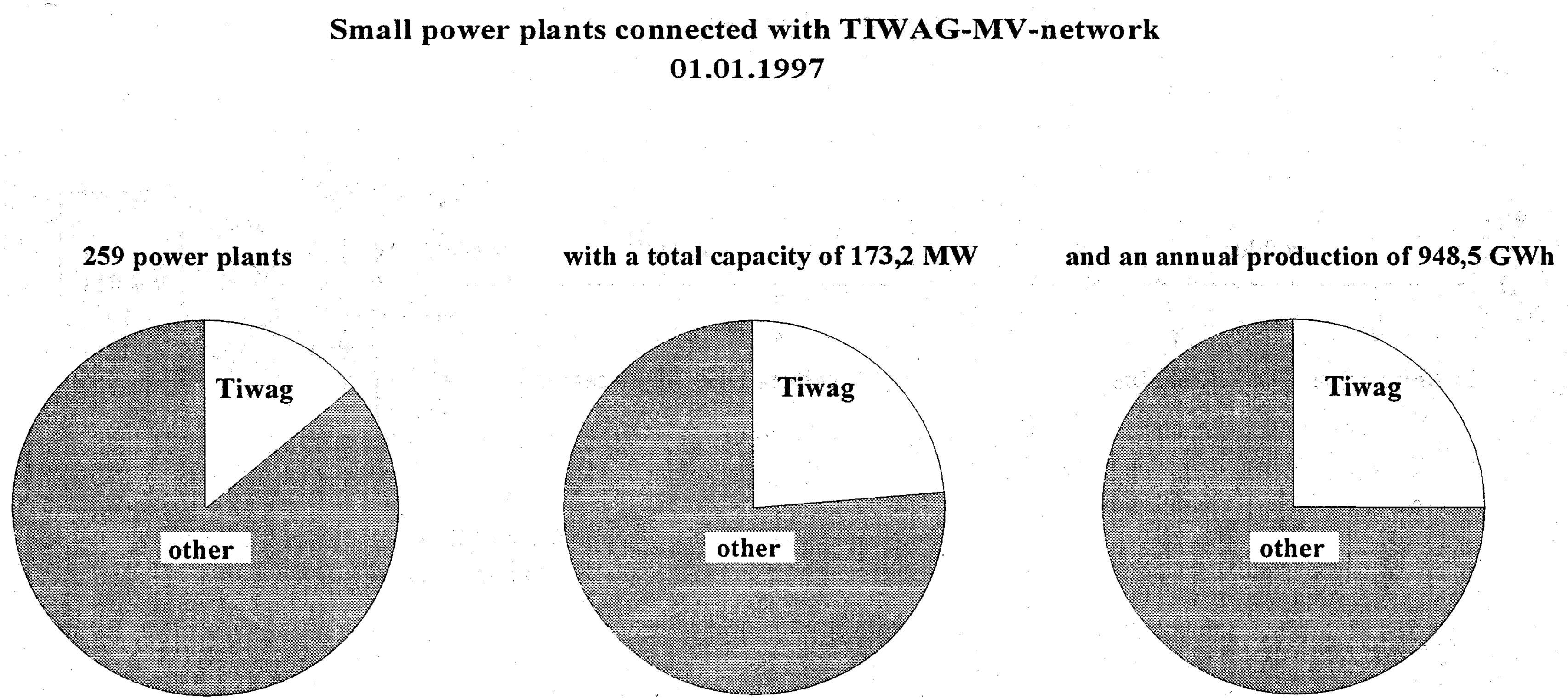

Figure 2: As of 01.01.1997 259 small power plants with an installed total capacity of 173,2 MW were connected to the TIWAG-MV-network

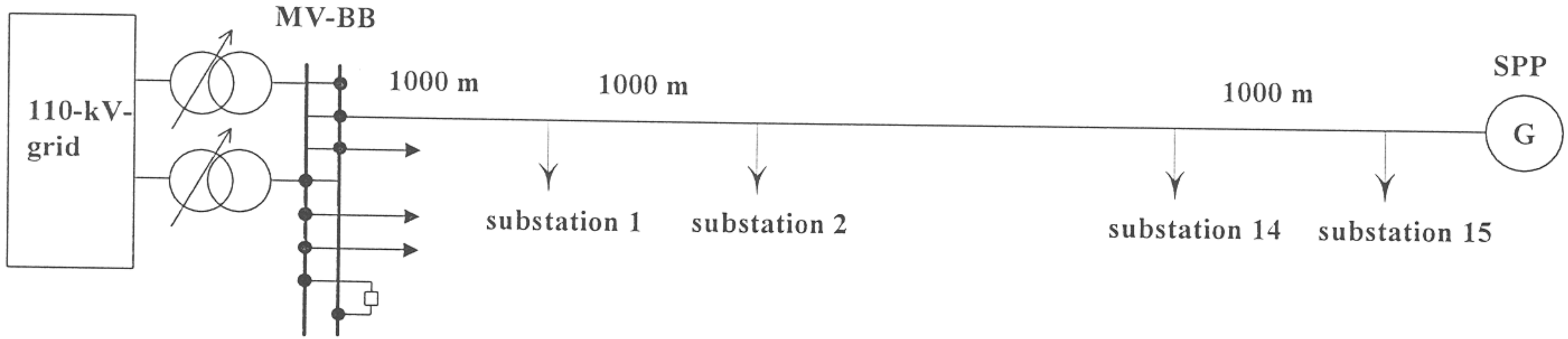

Figure 3: MV-model line with 15 substations
Each substation has the same load

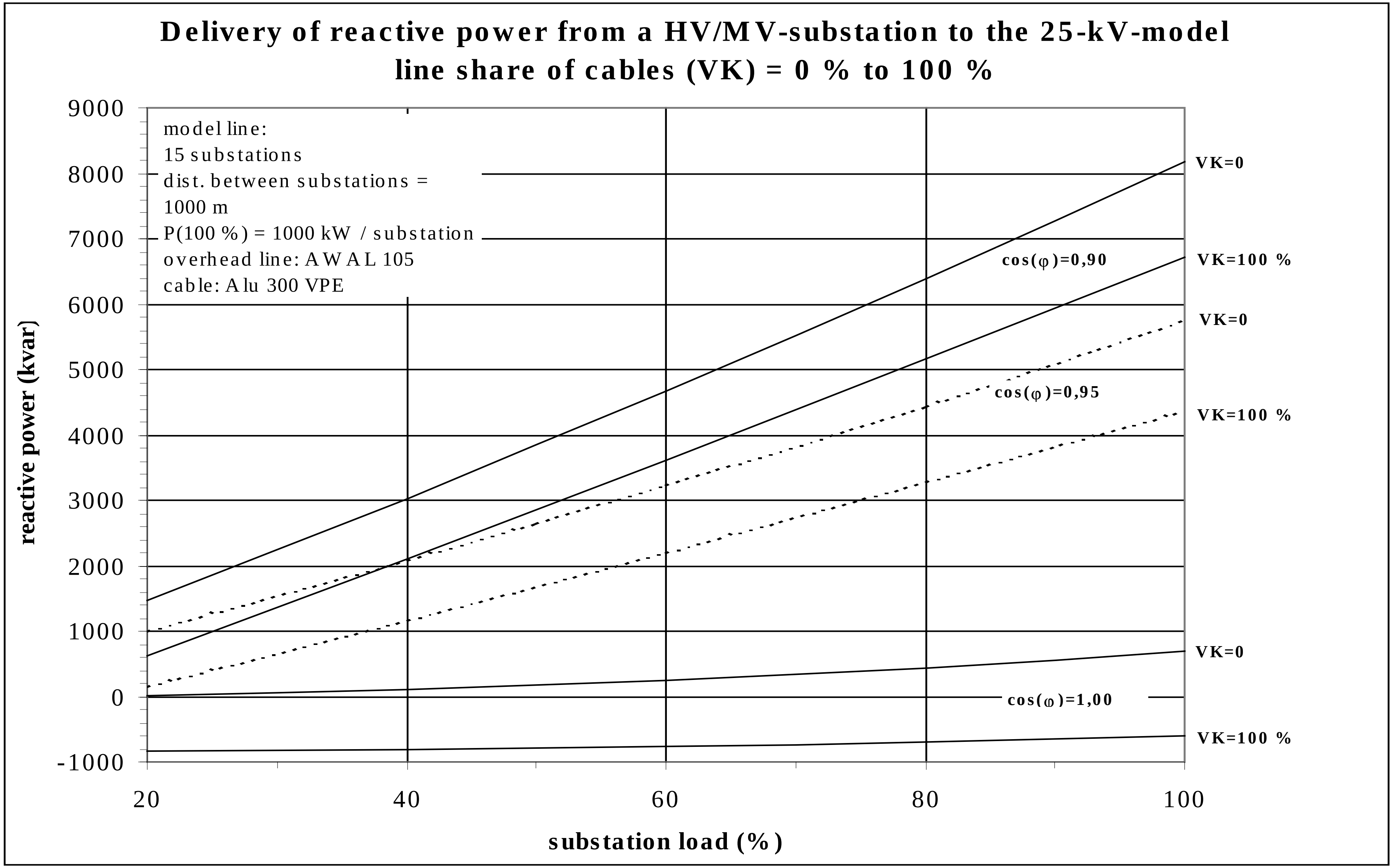

Figure 4: The demand of reactive power of a line depends much more on the load of the substations and their power factor than on the share of the cables.

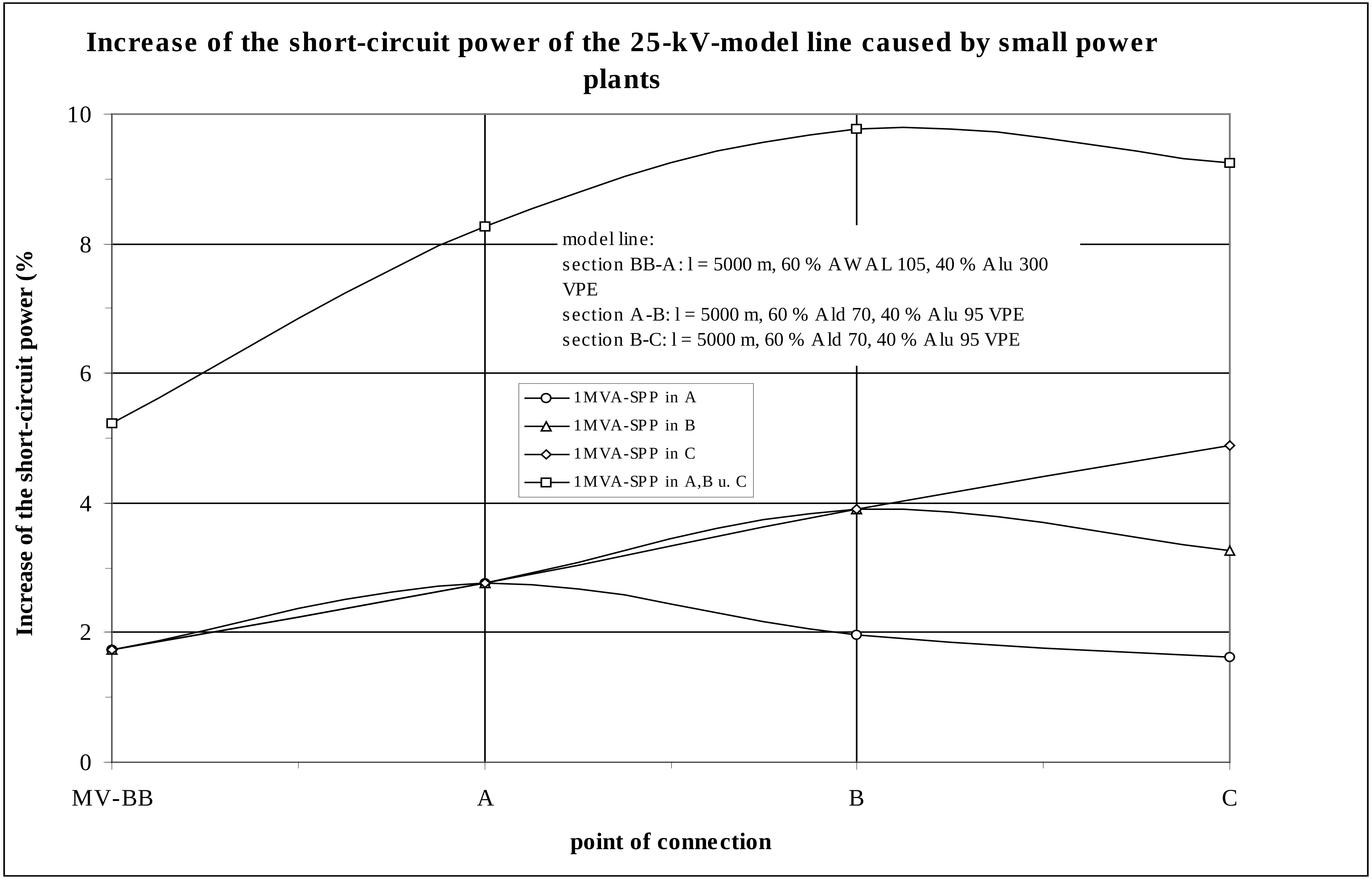

Figure 5: Each small power plant causes an increase of the short circuit power.
This increase can be up to approx.5% per MVA of the small power plant..

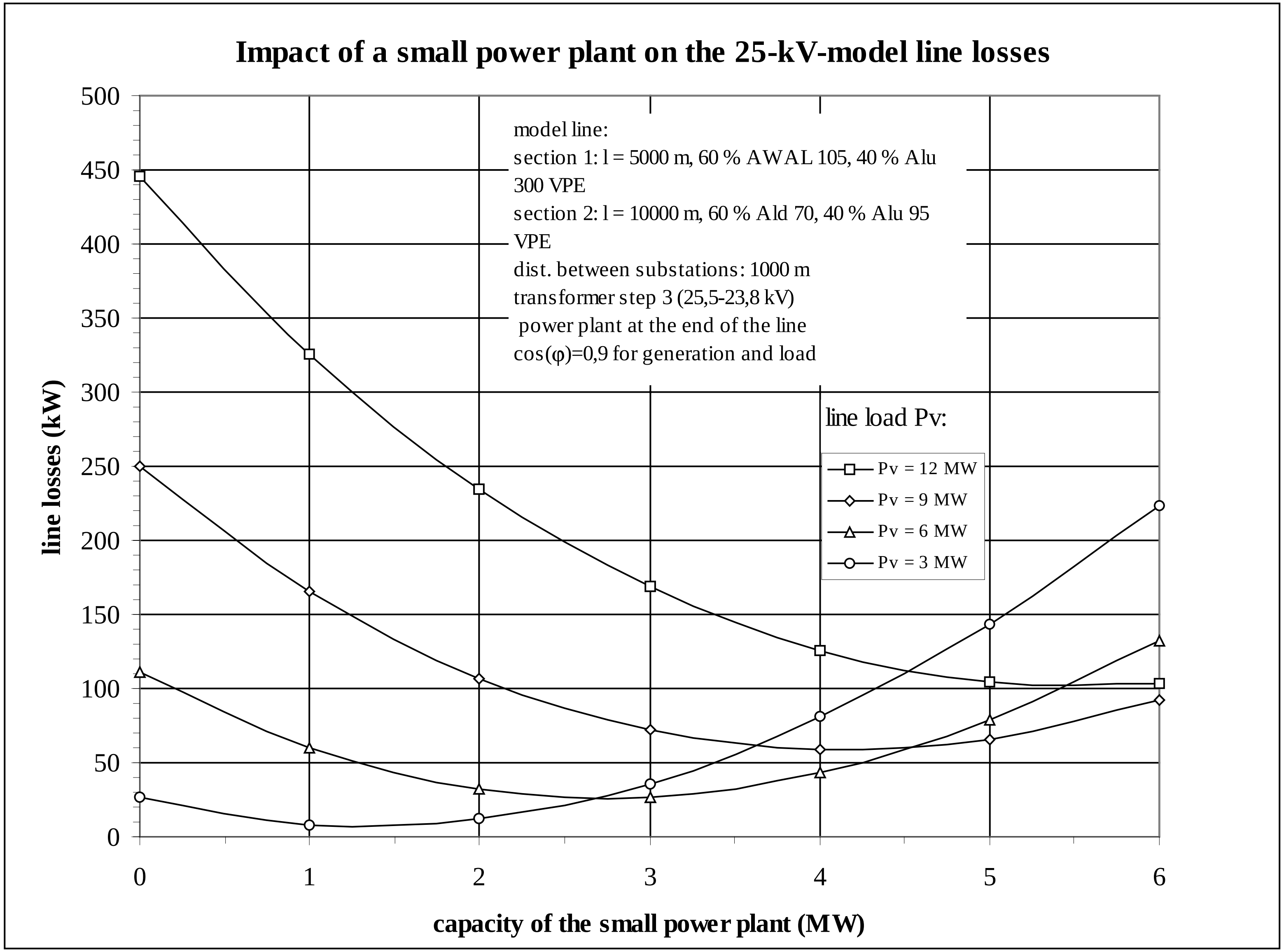

Figure 6: Depending on the relation between generation and load line losses can be increased or decreased by a small power plant

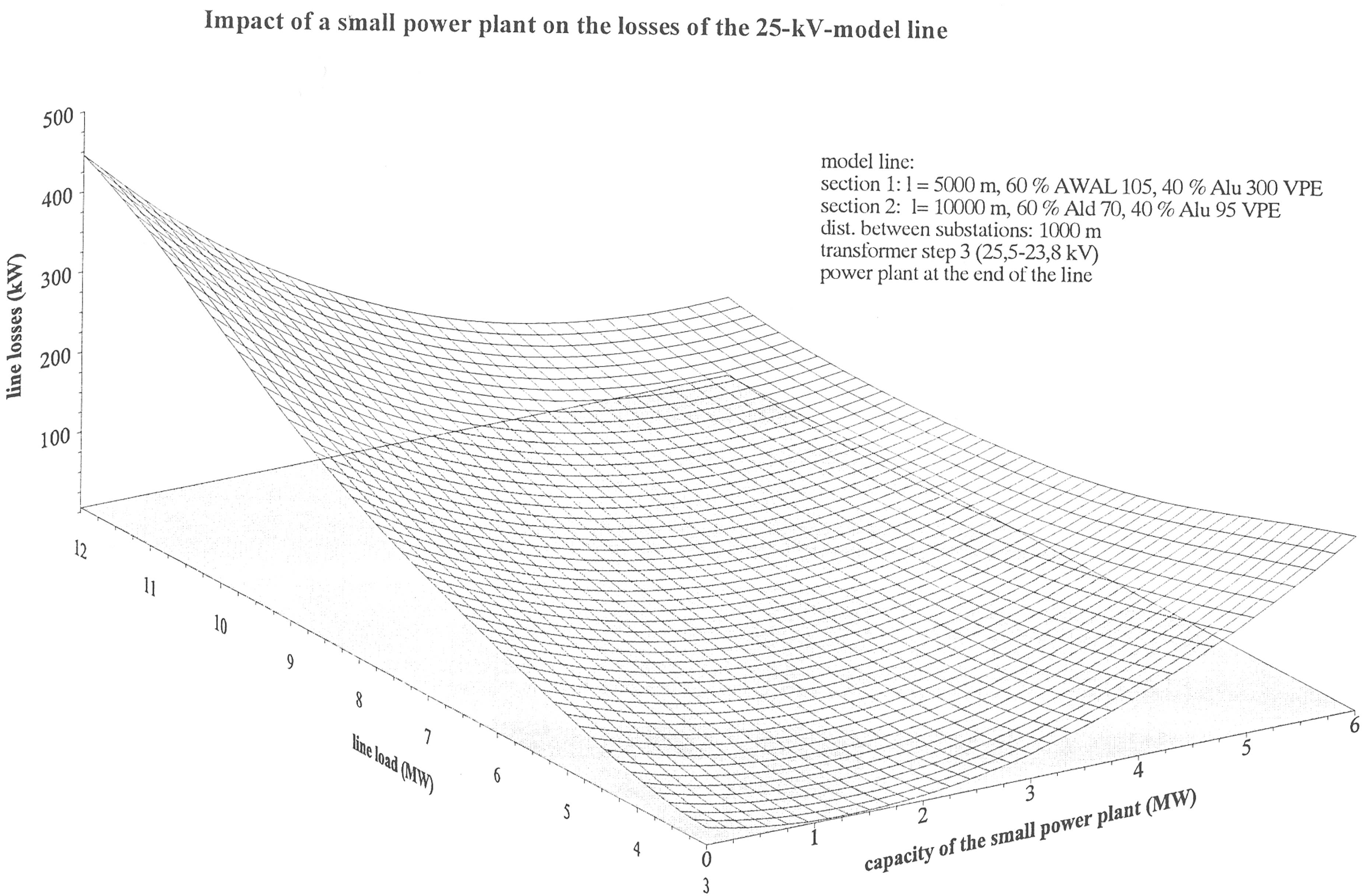

Figure 6A: Three-dimensional view of the line losses depending on load an generation

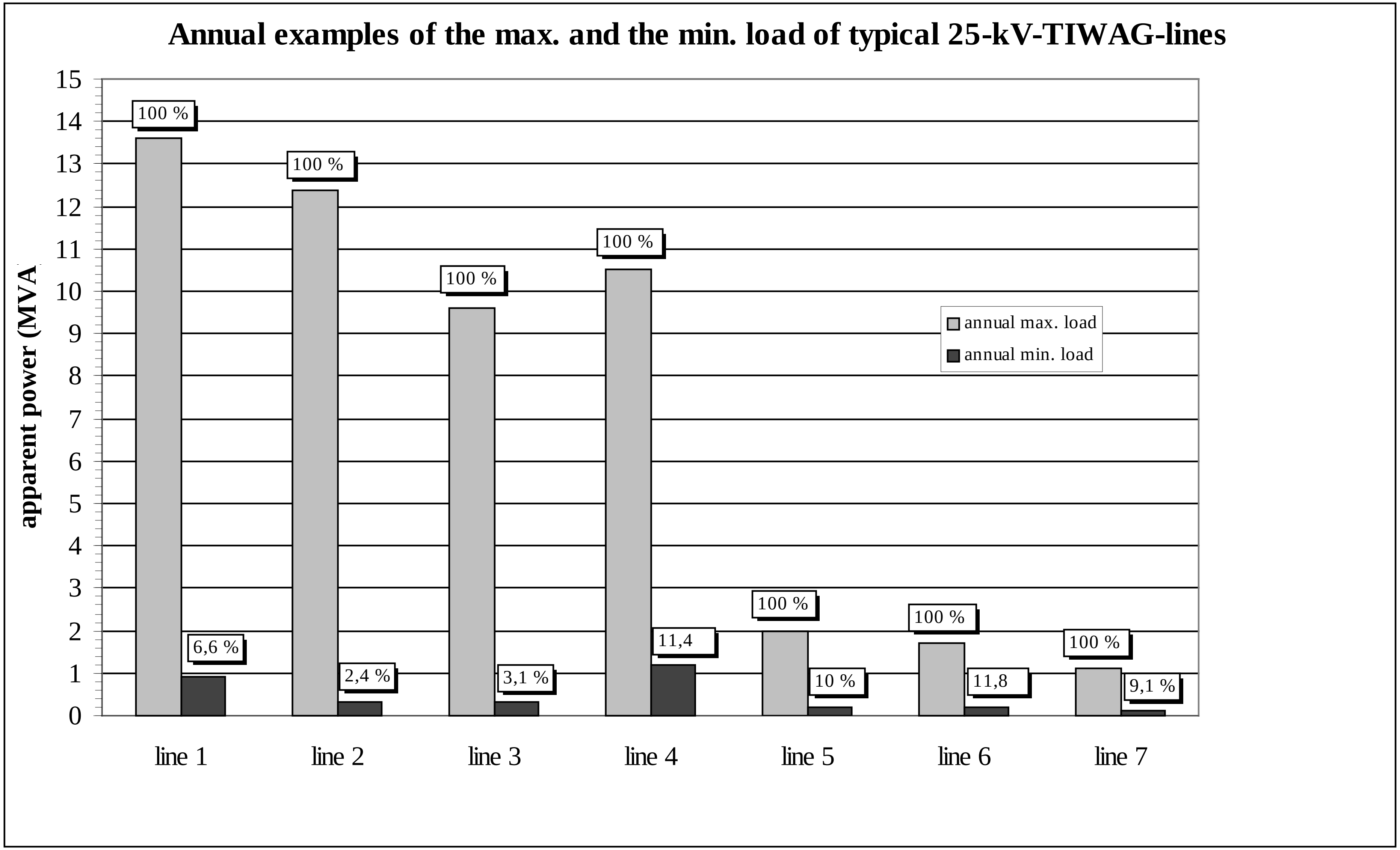

Figure 7: Frequently the min load of MV-lines reaches only a few 100 KVA
However, lines with a high max. load can have a very low min. load as well

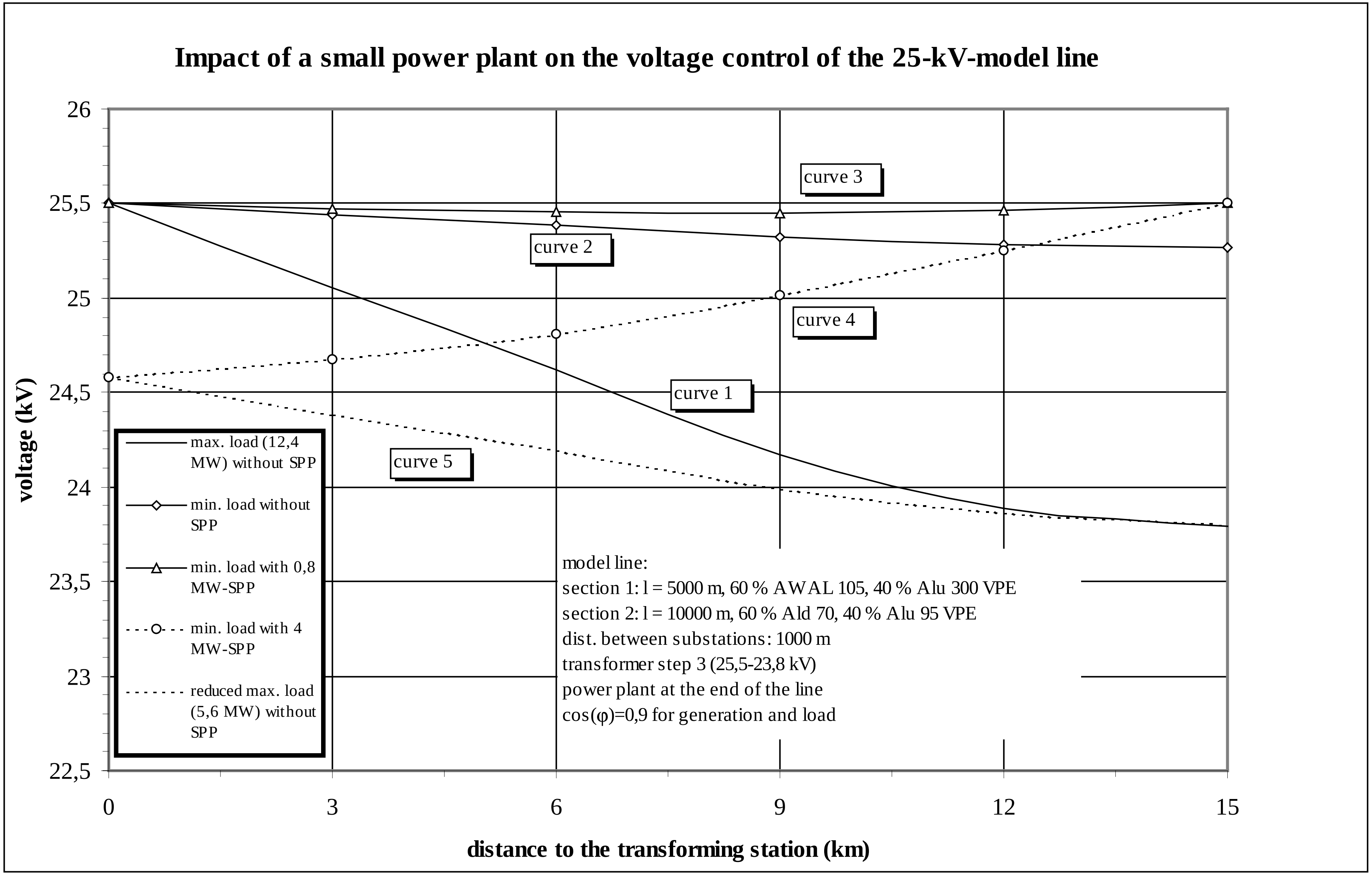

Figure 8: Depending on the min. load the voltage of the transforming station has to be reduced if the generation reaches a certain power. This causes a reduction of the max. supplyable load.

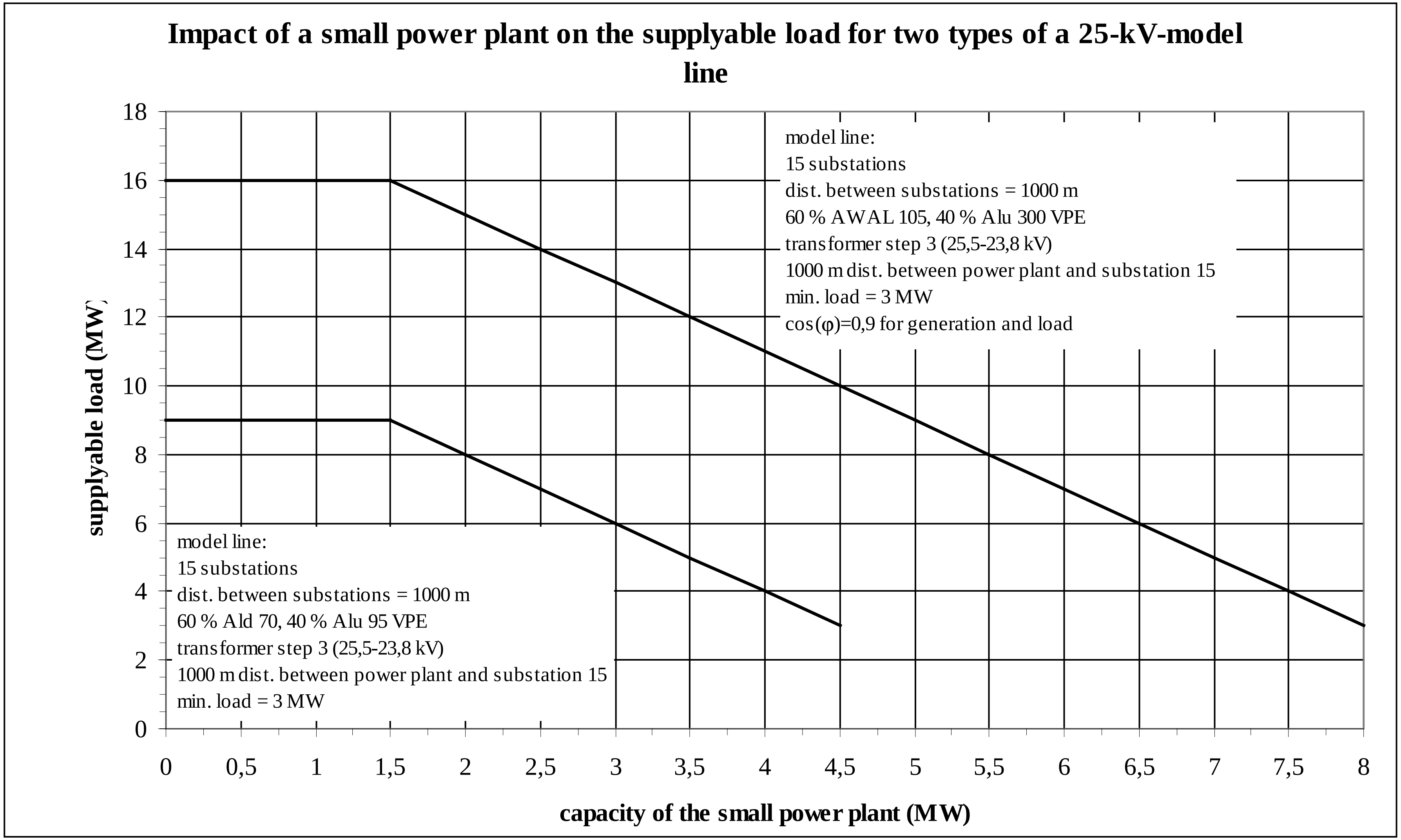

Figure 9: The supplyable consumer load decreases if the capacity of the small power plant exceeds 50% of the lines min. load.