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The Effects of Distributed Generation on System Power Losses

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Keywords
Power Losses; Power Plants; Substations; DIgSILENT PowerFactory; Distributed Generation

Abstract

Electrical energy needs is increasing in Turkey and whole World day by day. So, many small plants have been established for energy needs. Therefore, power systems are becoming more complex but powerful. A part of distributed power is loosed in grid. Moreover power losses have increased parallel to the rising in electrical energy consumption. Electrical parameters must be within certain limits according to regulations. So, electric companies must renew the transformers and distribution lines to ensure the quality of electricity. This investment may be delayed by planning the power connection nodes. Today, this planning is done by using computer software easily. Trabzon Arsin organized industrial zone was chosen to see how power losses changing with different location of DG. The zone is modeled and simulated using DIgSILENT PowerFactory software. The software analysis showed that active power losses are changed significantly

Dağıtılmış Üretim Kaynaklarının Şebekedeki Güç Kaybına Etkileri

Anahtar kelimeler
Şebeke Kaybı; Enerji Santralleri; Transformatör Merkezleri; DIgSILENT PowerFactory; Dağıtılmış Üretim Kaynakları

Abstract

Türkiye'de ve dünyada elektrik enerjisine ihtiyaç her geçen gün artmaktadır.Bu enerji ihtiyacı için birçok küçük güçte elektrik santrali inşa edilmiştir.Bu nedenle şebekelerin gücü artmış ancak şebeke daha karmaşık hale gelmiştir.Elektrik şebekesinde iletilen gücün bir kısmı şebekede kaybolmaktadır. Bu kayıp, tüketim miktarı ile artmaktadır.Ancak elektrik parametreleri yönetmeliklere göre belirli bir değer aralığında olmalıdır. Bu yüzden dağıtım şirketleri elektrik kalitesini sağlamak için trafo ve dağıtım şebekeleri yenilemek zorundadır.Bu yatırımlar güç bağlantı noktalarının planlanması ile ertelenebilir.Günümüzde bu planlamalar yazılımlar ile kolayca gerçekleştirilmektedir.Dağıtılmış üretim kaynağının farklı noktalardan şebekeye bağlanması durumunda güç kaybının nasıl değiştiğini görmek için Trabzon Arsin Organize Sanayi Bölgesi seçilmiştir.Bubölge DIgSILENT PowerFactory programı kullanılarak modellenmiş ve analiz edilmiştir.Analizde, elektrik güç kaybının farklı güç bağlantı noktaları için önemli oranda değiştiği gözlemlenmiştir.

1. Introduction

Electrical energy needs is increasing gradually in whole World. Rarely, this need creates serious problems such as power failures and voltage drop, etc. For solving this problems many distributed generation (DG) has built and it will expected to increase in the future.

DG can be defined as small size generators operating isolated or connected to system. DG may be conventional generators or photovoltaics, wind turbines, fuel cells and micro turbines (Ackermann et al., 2001). It has many advantages in system. For example, unloading transmission and distribution system, decreasing active system power losses (PL), improving power quality and reliability(Nuroğlu and Arsoy2008). Arsin substation center (ASC) has a 8 feeders. 7 feeders are active and one feeder is spare. Feeders are shown in Fig 1. Substation nominal power is 75 MVA (Çoruh EDAŞ).

Power Consumption of ASC on different dates shown in Table 1. Sometimes, F7 and F8 feeder's power consumption is negative due to production of DG. Also, all feeders have a good power factor (PF). Especially PF of Trabzon Arsin Organized Industrial Zone (OIZ) is about 1. (web.src.1)

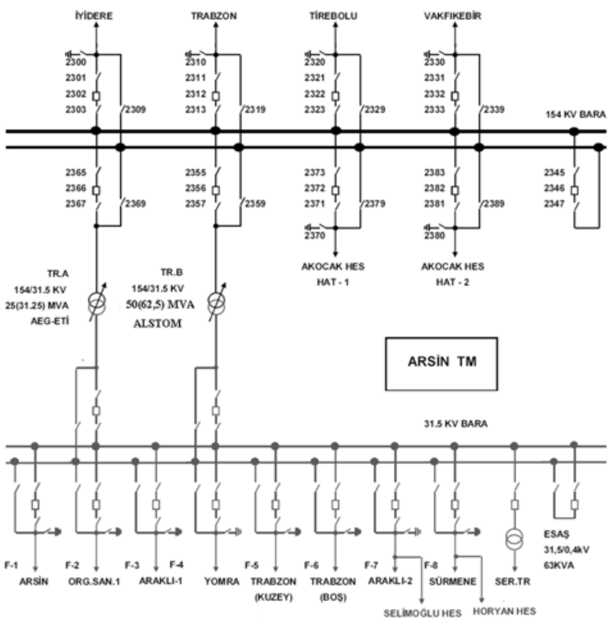


Figure 1. Single Line Diagram of Substation Center

Table 1. Power Consumption of Substation Center at 13.01.2015, 00:30 and 29.01.2015, 17:30

Feeder's Name	P(MW) 13.1.15	Cos ϕ	P(MW) 29.1.15	Cos ϕ
Arsin	1,71	0,955	2,98	0,972
Arsin OSB	2,68	0,999	6,62	0,999
Arakli-I	8,35	0,995	14,93	0,988
Arakli-II	-4,55	0,971	3,42	0,984
Surmene	-3,68	0,996	-1,02	0,979
Yomra	4,1	0,991	6,2	0,990
Trabzon K.	5,3	0,991	8,3	0,990

Type of Trabzon Arsin OIZ feeder is a radial. There is spare line between the connecting node-I and node-II as shown in Fig. 3. This line is activated whenever there is maintenance or fault. Arsin OIZ has about 81 distribution transformers and total nominal power of these transformers is about 47 MVA. Information number and and nominal apparent of distribution transformers shown in Table 2.

Table 2.Nominal Power of Distribution Transformer and numbers

S(MVA)	0.16	0.25	0.4	0.63	0.8	1	1.25	1.6	2.5
Number	7	22	23	8	2	10	2	3	3

Also, these transformers have a different technical specification such as short-circuit voltage (%uk), winding connection type (COT), X/R ratio and neutral resistance (NER) as shown in Table 3.

In this study, it is assumed that the transformer give energy to only Arsin OIZ and other feeders is opened. The objective of this study is to determine the effects of DG on system power losses and voltage profiles of industrial zone while the location of DG is varied. A briefsingle line diagram power consumption, technical information of power transformers and DG given first. Then modeled diagram and power connection nodes are introduced. System power losses and voltage profile changes are given graphical form for different location of DG to compare their effects. The last section finally summarizes the main conclusions listed from the simulation results.

Table 3. Information of Distribution Transformers

S(MVA)	%uk	X/R	COT	NER(Ω)
2.5	6	6,17	Dyn11	-/0
2	6	5,62	Dyn11	-/0
1.6	6	5,55	Dyn11	-/0
1.25	6	5,68	Dyn11-	-/0
1	6	5,63	Dyn11	-/0
0.8	6	5,42	Dyn11	-/0
0.63	4,5	4,14	Dyn11	-/0
0.4	4,5	3,53	Dyn11	-/0
0.25	4,5	3,05	Dyn11	-/0
0.16	4,5	2,64	Yzn11	-/0
0.1	4,5	2,08	Yzn11	-/0
0.05	4,5	1,49	Yzn11	-/0

2. Simulation Model

Trabzon Arsin OIZ feeder is modeled and analyzed using DIgSILENT PowerFactory software. The main objective is to find the feeder power losses according to different location of DG. Actually, there isn't any DG in OIZ. But in the future DG may be established for prevent to power failures. So DG is connected to three cabins one by one to find their effect on power losses.

2.1.Technical Information of Arsin Substation and Organized Industrial Zone

Total rated nominal power of Trabzon Arsin OIZ is about 47 MW. But generally active power needs is changed 2 to 11 MW. The rated power (MW) demand from substation is shown in Fig. 2. for January 2015. ASC has two power transformers as

TR-A and TR-B. Transformers work together when power demand is above 50 MWA. Otherwise transformers work alone. Technical Information of power transformers is shown in Table 4.

For this model, maximum power consumption of this feeder is about 24 MVA. So it was assume that only TR-A is works in ASC.

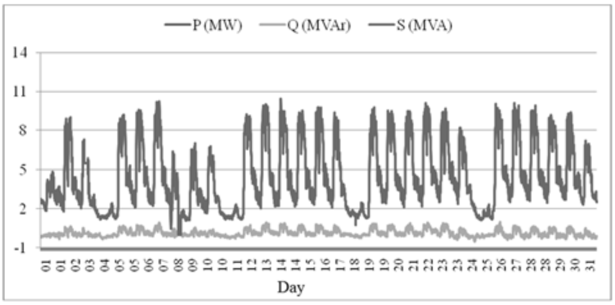


Figure 2. Power Consumption of Arsin OIZ

It was assumed that DG connects each of connecting nodes (cabin) separately. The first cabin is located at the entrance (Case-III), secondary cabin is located in the center (Case-II), the third cabin is located in the end of the longest distribution line (Case-I) in Arsin OIZ.

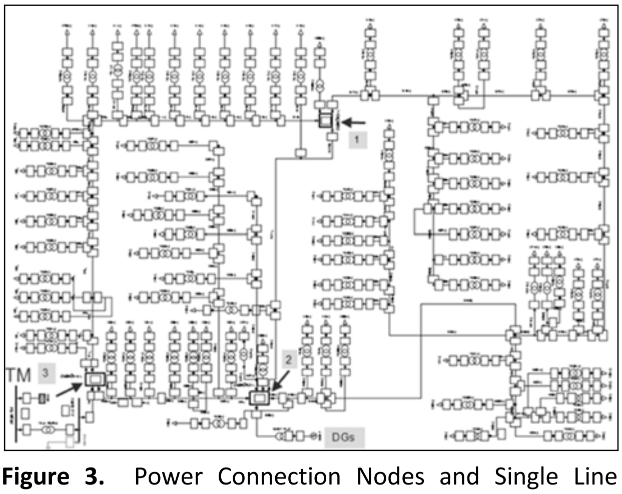


Figure 3. Power Connection Nodes and Single Line Diagram of Arsin OIZ on DIgSILENT PowerFactory Software

Power and distribution transformers, transmission and distribution lines, loads are modeled using DIgSILENT PowerFactory computer software. The modeling data is real parameters and technical information of DG shown in Table 5.

DG was assumed to operate in over-excited region and produced 5 MW active powers.

Table 4. Technical Information of Transformers

Parameter	TR-A	TR-B
Nominal Power	25 MVA	50 MVA
Nominal Voltage	154/31,5 kV	154/31,5 kV
Connection Type	YNyn0	YNyn0
Neutral Resistance	0/20 ohm	0/20 ohm
X/R Rate	20	50
%uk	9,12	12,31
Frequency	50 Hz	50 Hz

Table 5. Technical Information of DG

Parameter	Value
Xd	1,1227
X'd	0,2110
X"d	0,1568
Xq	0,6195
X'q	0,6195
X"q	0,1850
P	5 MW
Cos Ø	0,85

2.2.System Power Losses Calculation

Transmission power losses are about 4-8% and distribution power losses are about 4-6 % technically. Eventually, system power losses between the power plants and consumers is in the range between 8- 15% (web.src.2) System power losses in distribution systems are dominated by thermal losses in the lines and cables. These losses increase quadratic with the current on the distribution lines and cables (Troster et al., 2013).

$$P_L = R_{Line}.I^2 \quad (1)$$

Electrical energy distributed via overhead lines and underground cables from power transformers to distribution transformers. In this model, 2,5 km pigeon type transmission line is between connection node-I and substations. Type of others distribution overhead lines is swallow and type of whole cables is N2XSY in this model. System power losses have been studied for cases in two situations. Cases can be listed as no DG, DG at connecting node-I, DG at connecting node-II, and DG at connecting node-III in system. So, effect of connecting node on losses is investigated in situation-I and II. Effect of PF on losses is investigated in situation-III and system voltage profile is obtained in situation-IV.

2.2.1Situation-I

In situation-I, power consumption of Arsin OIZ has been set about 12 MW (25 % of total nominal power).

System power losses value is approximately 0, 25 MW without any DG and shown in Fig. 5. Also system power losses changing by location of DG and all cases compare shown Fig.4.

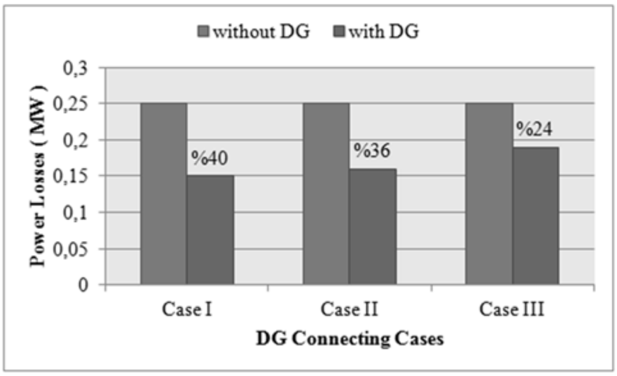
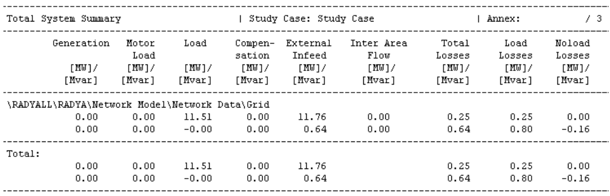


Figure 4. Power Losses for All Cases for Situation-I



Total System Summary | Study Case: Study Case | Annex: / 3

	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Inter Area Flow [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
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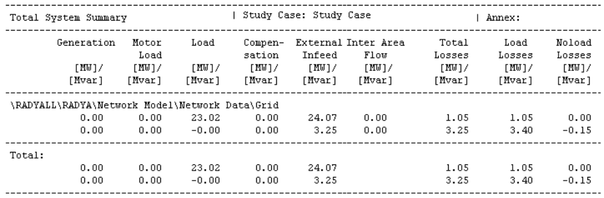
	0.00	0.00	11.51	0.00	11.76	0.00	0.25	0.25	0.00
	0.00	0.00	-0.00	0.00	0.64	0.00	0.64	0.80	-0.16
Total:									
	0.00	0.00	11.51	0.00	11.76		0.25	0.25	0.00
	0.00	0.00	-0.00	0.00	0.64		0.64	0.80	-0.16

Figure 5. System Power Losses Output on DIgSILENT PowerFactory Software for Situation-I

2.2.2Situation-II

In situation-II, power consumption of Arsin OIZ has been set about 24 MW (50 % of total nominal power).

System power losses value is approximately 1, 05 MW without any DGand shown in Fig. 6. It is shown in Fig 7 about system power losses changing by location of DG and all cases compare.



Total System Summary | Study Case: Study Case | Annex:

	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Inter Area Flow [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
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	0.00	0.00	23.02	0.00	24.07	0.00	1.05	1.05	0.00
	0.00	0.00	-0.00	0.00	3.25	0.00	3.25	3.40	-0.15
Total:									
	0.00	0.00	23.02	0.00	24.07		1.05	1.05	0.00
	0.00	0.00	-0.00	0.00	3.25		3.25	3.40	-0.15

Figure 6. System Power Losses Output on DIgSILENT PowerFactory Software for Situation-I

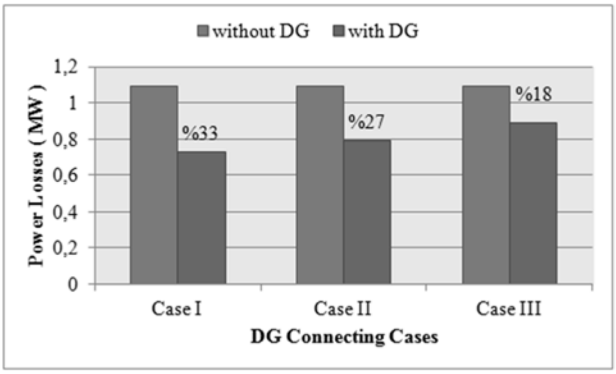

Figure 7. Power Losses for all cases for Situation-II

2.2.3Situation-III

In situation-III, The effect of power factor (P_F) on power losses in MW (P_L) was examined. P_F was changed from 0, 95 to 1.Feeder powerconsumption is 24 MW in this model and power losses given in Table 6.

Table 6. Power Losses Changes with Power Factor

P_F	0,95	0,96	0,97	0,98	0,99	1
P_L(MW)	1,15	1,14	1,13	1,11	1,09	1,05

2.2.4Situation-IV

In situation-IV, The effect of DG on voltage profile was examined. Feederpower consumptionis about 24MW. First, the voltage profile is obtained without any DG on system and shown in Fig. 8.

Voltage profile is obtained for case-I and shown in Fig. 9. Finally, voltage profile values for connecting node for all cases are obtained.

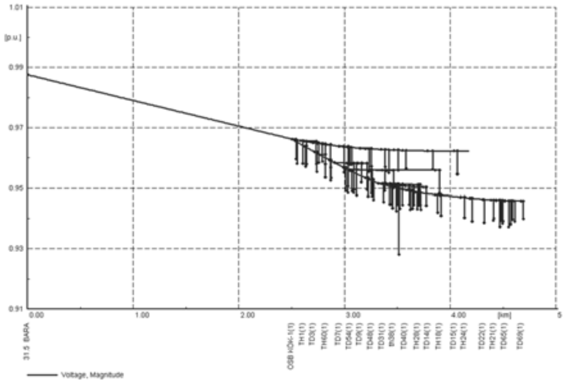

Figure 8 . Voltage Profile for No DG

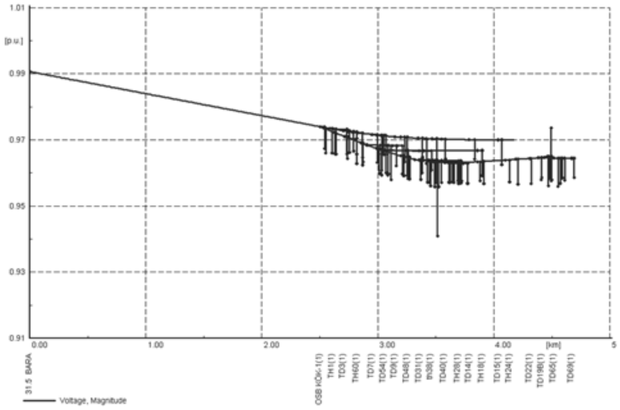

Figure 9. Voltage Profile for Case-I

3. Results and Discussion

DG has many advantages in transmission and distribution system. The following conclusions can be summary from this study.

• System power losses are decreased maximum %40 according to feeder's power demand from substation and DG power production.

• System power losses has decreased up to %8 approximately while power factor changed from 0,95 to 1.

• Nodes voltage level is increased through DG

• DG is given reactive power to feeders. So line efficiency is increased and system power losses are decreased remarkably.

• Also, using different control methods for DG placing to different nodes may decrease power losses significantly than results of this study (Tan et al.,2012;Chiradeja and Ngaopitakkul 2013).

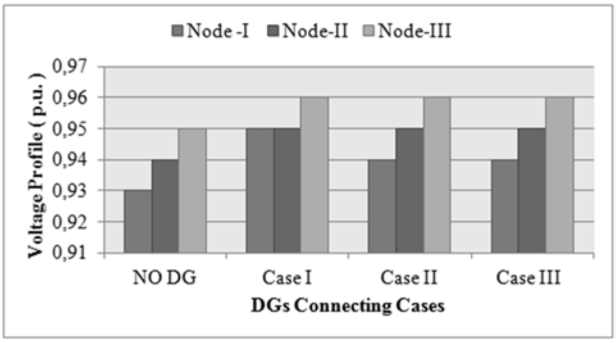

Figure 10. Arsin OIZ Voltage Profiles for All Cases

4. Conclusions

The simulation showed that active power loss is changed with power connection node and power factor. So,DGs and other power sources electrical connection points have increased efficiency significantly.

Therefore electrical networks must be simulated and found best power connection nodes for efficiency.

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