18.01.2019

MIDDLE EAST TECHNICAL UNIVERSITY ELECTRICAL-ELECTRONICS ENGINEERING DEPARTMENT

EE474 DISTRIBUTION SYSTEMS

Fall 2018

TERM PROJECT 3: Simulation Task in PSS/Sincal Environment

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1. INTRODUCTION

This report contains simulations of a MV (34.5kV) distribution system in PSS/Sincal environment. The aim of simulations is to find load voltages and losses in the system, whereas the aim of the project is to introduce one of the most used power system simulators for the planning, modeling, and analysis of electrical networks in the sector to the students.

In the first and second parts of the term project, load voltages and losses in defined networks under the specified conditions are found. Also, in the project definition findings on these simulation results, i.e. discussion on the results, comparison of found values, etc. are asked as a third task. Those findings are given in sections that belong to each task.

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2. TASKS

In this project, 34.5 kV infinite bus supplies a load of 30 MW. Since in PSS/Sincal, all network elements must be assigned to an electrical subnetwork, 34.5kV medium voltage level and 0.4kV low voltage level are created with ''Network Level'' and named as ''Medium Voltage'' and ''Low Voltage'', respectively.

All cables in the network are 240x3+25 mm^2 copper cables. To add cable parameters to the simulation, product catalog of HES Kablo[1] is used, the parameters can be seen in Figure 1.

BOYUT VE AĞIRLIKLAR				ELEKTRİKSEL ÖZELLİKLER				
Normal Kesit	Dış Çap (Yaklaşık)	Net Ağırlık (Yaklaşık)	Sevk Uzunluğu	İletken DC Direnci 20 °C Max	Çalışma İndüktansı (Yaklaşık)	İşletme Kapasitesi (Yaklaşık)	Akım Taşıma Kapasitesi (A)	
mm ²	mm	kg/km	m	ohm/km	mH/km	µF/km	Toprakta 20 °C	Havada 30 °C
3x25/16	49.5	3150	1000	0.727	0.417	0.146	148	143
3x35/16	51.5	3600	1000	0.524	0.397	0.160	178	173
3x50/16	54.5	4300	1000	0.387	0.377	0.175	210	206
3x70/16	58.5	5200	500	0.268	0.356	0.196	256	257
3x95/16	62.5	6300	500	0.193	0.339	0.218	307	313
3x120/16	66.5	7350	500	0.153	0.325	0.240	349	360
3x150/25	69.5	8550	500	0.124	0.315	0.258	392	410
3x185/25	74.0	10000	500	0.0991	0.305	0.280	443	469
3x240/25	80.5	12200	250	0.0754	0.292	0.315	513	553
3x300/25	85.5	14450	250	0.0601	0.284	0.343	576	635
3x400/35	93.0	18150	250	0.0470	0.273	0.385	650	731

Figure 1: Cable parameters

For the losses associated with transformers, I wanted to use datasheets of commercial products to find core and winding losses separately. However, I faced with two major issues.

Firstly, transformers with 34.5kV primary rated voltage values with closest MVar range to 30MVar were 25MVar or 60MVar ones, which means one is smaller than the other one is too big. Secondly, I chose 60MVar Minera Ex Explosive Area Transformer from Schneider Electric[2] which can be seen in Figure 2, however I could not find the associated datasheet showing its losses. Therefore; I decided to assign u_k=0.1 as we used this impedance value with transformers of similar ratings in EE471 course. Similarly, I decided that iron losses of transformers should be 2kW.

Technical Characteristics	
Rated power	Up to 60 MVA
Rated voltage	Up to 36 kV
Phases	Three-phase units (single-phase available on request)
Rated frequency	50 Hz or 60 Hz
Type of cooling	ONAN, (ONAF on request)
Other (optional)	Hermetically sealed or conservator; ground-mounted with normal, low noise or very low noise levels

Figure 2: Minera Ex Explosive Area Transformer

2.1. Determining Load Voltages and Losses with the Original Configuration

Original configuration of the network can be seen in Figure 3. Connectivity of the network is such that:

- ✓ Supply – DT-1: 2 km
- ✓ DT-1 – DT-2: 2 km
- ✓ DT-2 – DT-3: 3 km

Rated values of transformers are 30MVar and not to face any problems when losses are added while simulating the network, I chose full load values as 35MVar.

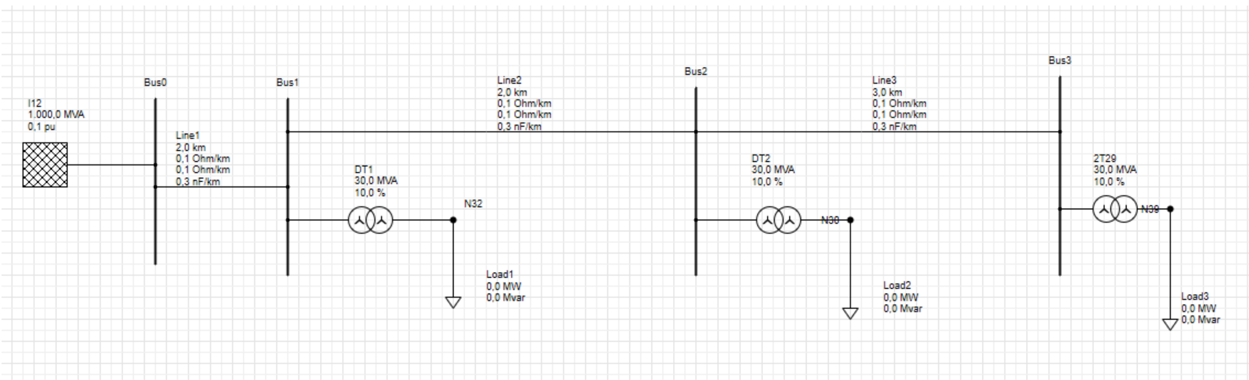

Figure 3: Configuration of the network in PSS/Sincal environment

CASE 1: The load is demanded at DT-3:

In this case, 30MWatt load is demanded at DT-3. To include transformer losses in the simulation, I assumed this load is demanded from the LV side of the transformer. As it can be seen from Figure 4, Sincal automatically writes associated branch and node losses on the model.

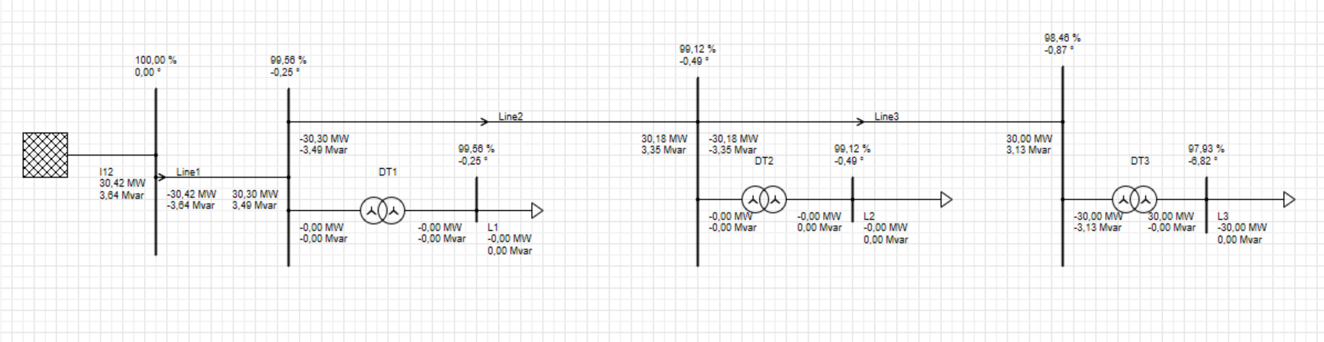

Figure 4: Load flow calculations of Case 1

In Figure 5, node results of load flow calculations are given. As expected, only nonzero values belong to the bus of Load 1 and the feeding bus. There are 0.422MWatt and 3.637MVar differences between them, which are total loses of the system and they are associated with transformer and cable losses. Also, all cables are used and voltage drop between Load 3 and the feeder is slightly bigger than 2%, which is a good value for a distribution system. To examine these losses in more detail, branch results of load calculation are given in Figure 6. As it can be seen from Figure 6, DT1 and DT2 cause only 2kW core loss. Winding losses of these transformers are zero because no load demanded from these nodes. Also, winding loss of DT3 is 3.128MVar which makes core loses insignificant.

Node	Network ...	P [MW]	Q [Mvar]	S [MVA]	V [kV]	V/Vn [%]	φV [°]	φVrot [°]	V/Vref [%]
Bus0	Medium Volta...	30,422	3,637	30,639	34,500	100,000	0,000	0,000	0,000
Bus1	Medium Volta...	0,000	0,000	0,000	34,348	99,559	-0,245	-0,245	0,000
Bus2	Medium Volta...	0,000	0,000	0,000	34,196	99,120	-0,493	-0,493	0,000
Bus3	Medium Volta...	0,000	0,000	0,000	33,970	98,465	-0,868	-0,868	0,000
Load1	Low Voltage	0,000	0,000	0,000	0,398	99,559	-0,245	-0,245	0,000
Load2	Low Voltage	0,000	0,000	0,000	0,396	99,120	-0,493	-0,493	0,000
Load3	Low Voltage	-30,000	0,000	30,000	0,392	97,934	-6,821	-6,821	0,000

Figure 5: Node results of load flow

Node 1	Node 2	Element ...	Element T...	Network ...	P [MW]	Q [Mvar]	S [MVA]	cosφ
Bus1	Load1	DT1	Two-Winding ...	Medium Volta...	-0,002	-0,000	0,002	-1,000
Load1	Bus1	DT1	Two-Winding ...	Medium Volta...	-0,000	-0,000	0,000	0,000
Bus2	Load2	DT2	Two-Winding ...	Medium Volta...	-0,002	-0,000	0,002	-1,000
Load2	Bus2	DT2	Two-Winding ...	Medium Volta...	-0,000	0,000	0,000	0,000
Bus3	Load3	DT3	Two-Winding ...	Medium Volta...	-30,002	-3,128	30,165	0,995
Load3	Bus3	DT3	Two-Winding ...	Medium Volta...	30,000	-0,000	30,000	1,000
Bus0	Bus1	Line1	Line	Medium Volta...	-30,422	-3,637	30,639	0,993
Bus1	Bus0	Line1	Line	Medium Volta...	30,303	3,492	30,504	0,993
Bus1	Bus2	Line2	Line	Medium Volta...	-30,301	-3,492	30,502	0,993
Bus2	Bus1	Line2	Line	Medium Volta...	30,182	3,346	30,367	0,994
Bus2	Bus3	Line3	Line	Medium Volta...	-30,180	-3,346	30,365	0,994
Bus3	Bus2	Line3	Line	Medium Volta...	30,002	3,128	30,165	0,995
Bus0		I12	Infeeder	Medium Volta...	30,422	3,637	30,639	0,993
Load1		L1	Load	Low Voltage	-0,000	0,000	-0,000	0,000
Load2		L2	Load	Low Voltage	-0,000	0,000	-0,000	0,000
Load3		L3	Load	Low Voltage	-30,000	0,000	30,000	-1,000

Figure 6: Branch results of load flow

CASE 2: The load is demanded at DT-1:

Now, 30MWatt load is demanded at DT-1, which is closer to the feeder; therefore, we must see decreased voltage drop and the effect of cable losses in this case. Load flow calculations on the model, node and branch results can be seen in Figure 7-8.

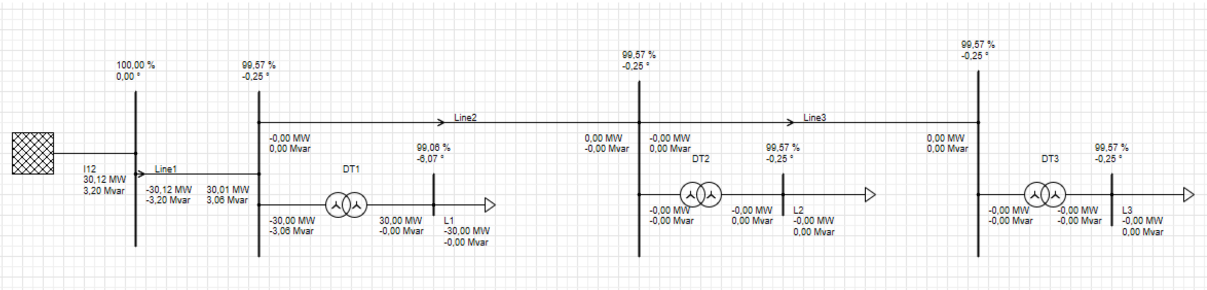

Figure 7: Load flow calculations of Case 2

Node	Network ...	P [MW]	Q [Mvar]	S [MVA]	V [kV]	V/Vn [%]	φV [°]
Bus0	Medium Volta...	30,122	3,199	30,292	34,500	100,000	0,000
Bus1	Medium Volta...	0,000	0,000	0,000	34,352	99,570	-0,246
Bus2	Medium Volta...	0,000	0,000	0,000	34,351	99,570	-0,246
Bus3	Medium Volta...	0,000	0,000	0,000	34,351	99,570	-0,246
Load1	Low Voltage	-30,000	-0,000	30,000	0,396	99,056	-6,065
Load2	Low Voltage	0,000	0,000	0,000	0,398	99,570	-0,246
Load3	Low Voltage	0,000	0,000	0,000	0,398	99,570	-0,246

Figure 8: Node results of load flow Case 2

Node 1	Node 2	Element ...	Element T...	Network ...	P [MW]	Q [Mvar]	S [MVA]	cosφ
Bus1	Load1	DT1	Two-Winding ...	Medium Volta...	-30,002	-3,058	30,157	0,995
Load1	Bus1	DT1	Two-Winding ...	Medium Volta...	30,000	-0,000	30,000	1,000
Bus2	Load2	DT2	Two-Winding ...	Medium Volta...	-0,002	-0,000	0,002	-1,000
Load2	Bus2	DT2	Two-Winding ...	Medium Volta...	-0,000	0,000	0,000	0,000
Bus3	Load3	DT3	Two-Winding ...	Medium Volta...	-0,002	-0,000	0,002	-1,000
Load3	Bus3	DT3	Two-Winding ...	Medium Volta...	-0,000	-0,000	0,000	0,000
Bus0	Bus1	Line1	Line	Medium Volta...	-30,122	-3,199	30,292	0,994
Bus1	Bus0	Line1	Line	Medium Volta...	30,006	3,057	30,161	0,995
Bus1	Bus2	Line2	Line	Medium Volta...	-0,004	0,001	0,004	-0,989
Bus2	Bus1	Line2	Line	Medium Volta...	0,004	-0,000	0,004	-0,996
Bus2	Bus3	Line3	Line	Medium Volta...	-0,002	0,000	0,002	-0,985
Bus3	Bus2	Line3	Line	Medium Volta...	0,002	0,000	0,002	1,000
Bus0		I12	Infeeder	Medium Volta...	30,122	3,199	30,292	0,994
Load1		L1	Load	Low Voltage	-30,000	-0,000	30,000	-1,000
Load2		L2	Load	Low Voltage	-0,000	0,000	-0,000	0,000
Load3		L3	Load	Low Voltage	-0,000	0,000	-0,000	0,000

Figure 9: Branch results of load flow

From node results we can see that voltage drop between DT1 and the feeder is less than half percent and voltage drop between DT1 and other transformers are zero because no current drawn from those cables.

Secondly, total real and reactive looses are 0.122MW and 3.199MVar (3.13MVar comes from winding loses in DT1), respectively. If we compare these values with previous ones. So, we can say that cable loses decreased significantly.

CASE 3: The load is equally distributed to DT-1, DT-2 and DT-3:

Load flow calculations on the model, node and branch results can be seen in Figure 10-12.

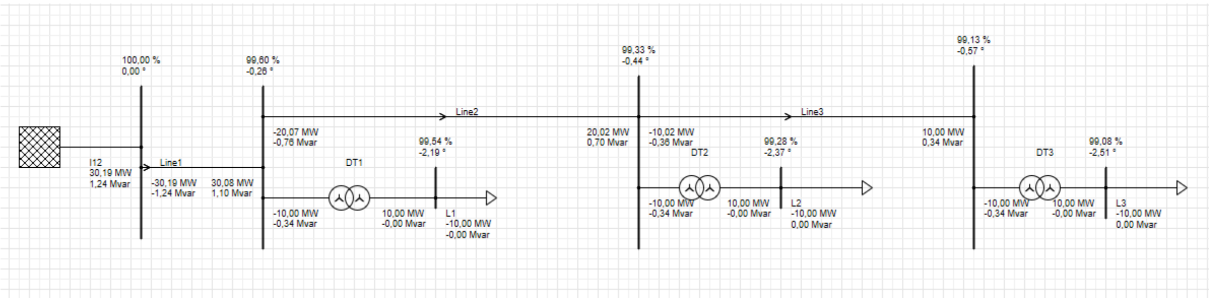

Figure 10: Load flow calculations of Case 3

Node	Network ...	P [MW]	Q [Mvar]	S [MVA]	V [kV]	V/Vn [%]	φV [°]
Bus0	Medium Volta...	30,193	1,242	30,218	34,500	100,000	0,000
Bus1	Medium Volta...	0,000	0,000	0,000	34,362	99,599	-0,261
Bus2	Medium Volta...	0,000	0,000	0,000	34,270	99,332	-0,436
Bus3	Medium Volta...	0,000	0,000	0,000	34,201	99,132	-0,567
Load1	Low Voltage	-10,000	-0,000	10,000	0,398	99,543	-2,188
Load2	Low Voltage	-10,000	0,000	10,000	0,397	99,276	-2,373
Load3	Low Voltage	-10,000	0,000	10,000	0,396	99,075	-2,512

Figure 11: Node results of load flow Case 3

Node 1	Node 2	Element ...	Element T...	Network ...	P [MW]	Q [Mvar]	S [MVA]	cosφ
Bus1	Load1	DT1	Two-Winding ...	Medium Volta...	-10,002	-0,336	10,008	0,999
Load1	Bus1	DT1	Two-Winding ...	Medium Volta...	10,000	-0,000	10,000	1,000
Bus2	Load2	DT2	Two-Winding ...	Medium Volta...	-10,002	-0,338	10,008	0,999
Load2	Bus2	DT2	Two-Winding ...	Medium Volta...	10,000	-0,000	10,000	1,000
Bus3	Load3	DT3	Two-Winding ...	Medium Volta...	-10,002	-0,340	10,008	0,999
Load3	Bus3	DT3	Two-Winding ...	Medium Volta...	10,000	-0,000	10,000	1,000
Bus0	Bus1	Line1	Line	Medium Volta...	-30,193	-1,242	30,218	0,999
Bus1	Bus0	Line1	Line	Medium Volta...	30,077	1,101	30,097	0,999
Bus1	Bus2	Line2	Line	Medium Volta...	-20,075	-0,764	20,089	0,999
Bus2	Bus1	Line2	Line	Medium Volta...	20,023	0,701	20,036	0,999
Bus2	Bus3	Line3	Line	Medium Volta...	-10,021	-0,363	10,028	0,999
Bus3	Bus2	Line3	Line	Medium Volta...	10,002	0,340	10,008	0,999
Bus0		I12	Infeeder	Medium Volta...	30,193	1,242	30,218	0,999
Load1		L1	Load	Low Voltage	-10,000	-0,000	10,000	-1,000
Load2		L2	Load	Low Voltage	-10,000	0,000	10,000	-1,000
Load3		L3	Load	Low Voltage	-10,000	0,000	10,000	-1,000

Figure 12: Branch results of load flow

From branch results, we can see that winding losses of transformers decreased to 0.336-0.340MVar, since current drawn through them decreased. (The reason why they are not equal to each other is that voltage drop between the transformer and feeder is different.) Now, total real and reactive losses are 0.193MW and 1.242MVar, respectively. Cable losses are 0.187MW and 0.16MVar. Overall, we can say that with even load distribution, we can decrease the apparent power loss significantly.

2.2. Determining Load Voltages and Losses with DT-4 Added

Now, there exists another DT4 such that DT-4 is connected to DT-2 via 2- km-long cable. Load demands are as follows:

- ✓ DT-1: 10 MW
- ✓ DT-2: 10 MW
- ✓ DT-3: 5 MW
- ✓ DT-4: 5 MW

Load flow calculations on the model, node and branch results can be seen in Figure 13-15. By adding a new transformer DT-2 and shifting 5MW load from DT-3 to DT-2 we added 2km cable and a new DT in the system however, we still managed to decrease overall power loss to 0.183MW from 0.193 MW and reactive power loss to 1.057MVar from 1.242MVar comparing to Case 3 in the previous task. The biggest impact on this transition is made by decreased winding losses. As it can be seen from Figure 15, when we decrease the load demand from 10MW to 5MW, winding loses of DTs decrease from 0.340MVar to 0.085MVar.

Overall, we can say that with even load distribution **in expense of cable and transformer investment**, we can decrease losses in the system.

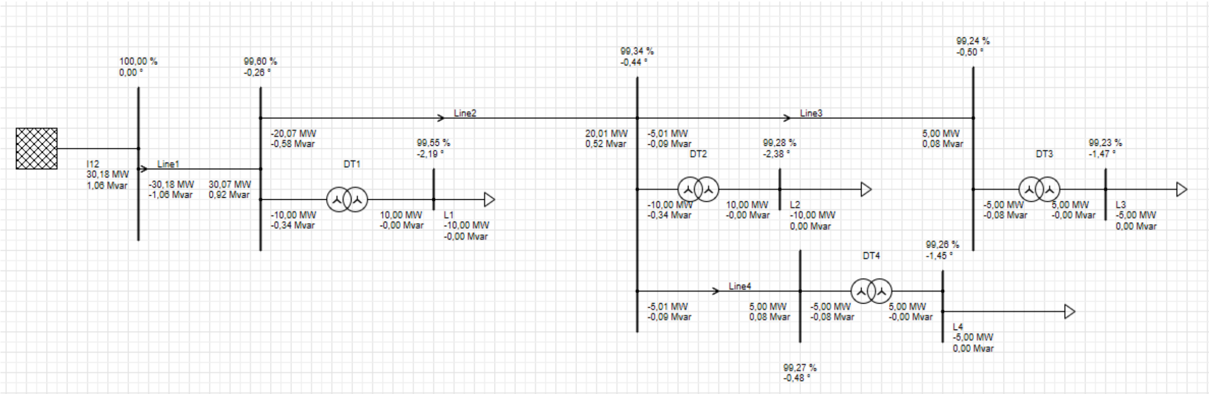

Figure 13: Load flow calculations

Node	Network ...	P [MW]	Q [Mvar]	S [MVA]	V [kV]	V/Vn [%]
Bus0	Medium Volta...	30,183	1,057	30,201	34,500	100,000
Bus1	Medium Volta...	0,000	0,000	0,000	34,363	99,602
Bus2	Medium Volta...	0,000	0,000	0,000	34,272	99,338
Bus3	Medium Volta...	0,000	0,000	0,000	34,238	99,241
Load1	Low Voltage	-10,000	-0,000	10,000	0,398	99,546
Load2	Low Voltage	-10,000	0,000	10,000	0,397	99,282
Load3	Low Voltage	-5,000	0,000	5,000	0,397	99,226
Bus4	Medium Volta...	0,000	0,000	0,000	34,249	99,273
Load4	Low Voltage	-5,000	0,000	5,000	0,397	99,259

Figure 14: Node results of load flow

Node 1	Node 2	Element ...	Element T...	Network ...	P [MW]	Q [Mvar]	S [MVA]	cosφ
Bus1	Load1	DT1	Two-Winding ...	Medium Volta...	-10,002	-0,336	10,008	0,999
Load1	Bus1	DT1	Two-Winding ...	Medium Volta...	10,000	-0,000	10,000	1,000
Bus2	Load2	DT2	Two-Winding ...	Medium Volta...	-10,002	-0,338	10,008	0,999
Load2	Bus2	DT2	Two-Winding ...	Medium Volta...	10,000	-0,000	10,000	1,000
Bus3	Load3	DT3	Two-Winding ...	Medium Volta...	-5,002	-0,085	5,003	1,000
Load3	Bus3	DT3	Two-Winding ...	Medium Volta...	5,000	-0,000	5,000	1,000
Bus4	Load4	DT4	Two-Winding ...	Medium Volta...	-5,002	-0,085	5,003	1,000
Load4	Bus4	DT4	Two-Winding ...	Medium Volta...	5,000	-0,000	5,000	1,000
Bus0	Bus1	Line1	Line	Medium Volta...	-30,183	-1,057	30,201	0,999
Bus1	Bus0	Line1	Line	Medium Volta...	30,067	0,916	30,081	1,000
Bus1	Bus2	Line2	Line	Medium Volta...	-20,065	-0,580	20,074	1,000
Bus2	Bus1	Line2	Line	Medium Volta...	20,014	0,517	20,021	1,000
Bus2	Bus3	Line3	Line	Medium Volta...	-5,007	-0,090	5,008	1,000
Bus3	Bus2	Line3	Line	Medium Volta...	5,002	0,085	5,003	1,000
Bus2	Bus4	Line4	Line	Medium Volta...	-5,005	-0,088	5,006	1,000
Bus4	Bus2	Line4	Line	Medium Volta...	5,002	0,085	5,003	1,000
Bus0		I12	Infeeder	Medium Volta...	30,183	1,057	30,201	0,999
Load1		L1	Load	Low Voltage	-10,000	-0,000	10,000	-1,000
Load2		L2	Load	Low Voltage	-10,000	0,000	10,000	-1,000
Load3		L3	Load	Low Voltage	-5,000	0,000	5,000	-1,000
Load4		L4	Load	Low Voltage	-5,000	0,000	5,000	-1,000

Figure 15: Branch results of load flow

3. CONCLUSION

To sum up, in this report simulations of a MV (34.5kV) distribution system in PSS/Sincal environment are discussed. In the first part of the project, load flows of different distributions of 30MW load among DTs in the same system are carried out. In the second part of the project adding new element to the system, the same load is distributed among DTs again.

From overall results of the simulations, we can say that in a distribution system such as this where cable lengths are relatively small, the most significant losses in the system are due to winding losses in DTs, whereas core losses can be omitted. However, cable losses cannot be overlooked for they are still considerably big.

From Case 2 and Case 1 where the load demand is further away from the feeder comparing to Case 2, we can say that the distance between the load and supply affects voltage drop and cable loses significantly and although we did not observe this problem in the project, bigger cable sizes might be needed for remote loads.

Case 3 shows that even load distribution in the same system results in less total losses observed on the supply bus.

Finally, results from the second part of the project yields that distribution in expense of cable and transformer investment we can create a more even load distribution in the system which results in smaller total loss of the system.

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[1] http://www.hes.com.tr/images/user_uploaded_files/katalog-35MB.pdf

[2 http://download.schneider-electric.com/files?p_enDocType=Catalog&p_File_Name=NRJED315628EN_%28web%29.pdf&p_Doc_Ref=NRJED315628EN