Short Circuit Analyzes Of Power System Of PETKIM Petrochemical Aliaga Complex

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Abstract- **This study presents short circuit simulations of a big Petro-Chemical Plant having both external and internal supplying facilities. Following the verification of the power system modeling, short circuit studies are conducted for four different operating conditions. 34.5 kV busbar withstand currents, 6.3 kV busbar withstand currents and relay settings/perceptions are discussed form the point of system extension.**

I. INTRODUCTION

Electric power distribution systems are the portions of the power delivery infrastructure that takes the electricity from the highly meshed, high-voltage transmission circuits and delivers it to customers and consumers. Quality of electrical energy in a big industrial plant is important both from the cost and the quality of the end-product and is therefore one of the basic concerns of today's competitive industry. Most of the quality problems arise because of inappropriate distributions system design.

One of the main tasks of power distribution system analysis is the short circuit studies. Bus voltages and line currents calculated for various types of faults are in turn used to obtain the rating of the protective switchgear and to determine proper relay settings for an adequate protection.

Short-circuit protection is the selection of equipment, placement of equipment, selection of settings, and coordination of devices to efficiently isolate and clear the faults with as little impact on customers as possible. On the other hand, reliability (long-duration interruptions) and on the power quality (voltage sags and momentary interruptions) issues are the important secondary goals of protection.

PETKiM Petrochemical Plant in Aliaga-Izmir/TURKEY is a petrochemical industry complex that consumes power in a very large scale. Its production is very sensitive, critical and highly depended on the power quality and on the interruptions. This brought the necessity of installing its own power production facilities in addition to the supply from Turkish National Power Transmission System (TEIAS). Short circuit capacity of TEIAS system is 6664 MW[1]. PETKiM is not generally satisfied with the quality of power supplied from TEiA§ and therefore take some measures to keep quality on top.

This study presents power system model of PETKiM and short circuit simulation results for the developed model by Dig-Silent PowerFactory software v. 11.1.86.

First, system model is constructed and simulations are conducted for two different loading configurations. The results of the simulations are compared with the measurements for the validity of the modeling.

After having satisfied the sufficient accuracy, short circuit analyses are carried out for four different operating configurations given by PETKiM authority. These operating configurations are then compared with each other from the following points of view to accomplish the best operating configuration.

- 34.5 kV busbar withstand short circuit currents,
- 6.3 kV busbar withstand short circuit currents,
- 34.5 kV relay settings,
- TEIAS relay settings,
- 34.5 kV system short circuit perception and
- expansion possibilities of the system

II. POWER GENERATION AND DISTRIBUTION SYSTEM OF PETKiM

Power generation system has 4 turbo-generators totally having 180 MW generation capacities. Two of them are of 80 MVA and are excited by 63 MW double-extraction, back pressure turbines. The task of these turbines is to transform extra high pressure Steam (XHS) generated by steam generation to high pressure steam (HS), medium pressure steam (MS) and low pressure steam (LS) needed by the process units. Moreover they generate electric power as secondary product. By these turbines the pressure of out coming LS is controlled. The remaining 25 MVA and 27,5 MVA generators are excited by condenser turbines controlled through the entering LS amount per seconds.

Electric power in PETKiM system is distributed through 34,5 kV buses. Double bus system named A/C and B/D is used for the sake of higher reliability. Main busses A, B, C and D are interconnected both in longitudinal and axial conductors providing several different operating configurations. There are 58 out-going switches supplying the cables going through the cable galleries to each cell. In addition there are 14 standby redundant spare switchgears. 34.5 kV cables feed 34,5/6,3 kV transformers in the cells. Transformer ratings depend on the requirement of the cells.

Generators are connected to the buses through four separate 10,5/34,5 kV transformers. Power supplied by the TEIA§ system is transferred to the system via two on load tap changing transformers of 154/35 kV 100 MVA. They are labeled as T21 and T22. Two reactors are serially connected to the secondary sides of the transformers to limit the short-circuit currents. In addition, one reactive power compensator is connected to 34,5 kV bus and there are three reactors connected between the buses.

There are 4726 electric motors for compressors, fans, blowers, pumps, extruders, centrifuges, mixer and valves at the cells. 95% of them are induction motors. Their ratings start from couple of Watts and goes up to 11 MW.

Generally motors having rated below than 150 kW are low voltage motors and are supplied from 0.4 kV low voltage outputs. There are 170 medium voltage motors rated above 150 kW and are supplied from 6.3 kV distribution system. Total installed capacity of these medium voltage motors is about 140 MW power.

Distribution cells have normally non-coupled two 6,3 kV busses fed from two separate 34,5 kV buses. Each transformer is designed to supply the needs of the cell if the other one is outaged either for maintenance or failure. All these design principles are the requirements of providing higher reliability.

6,3 kV buses feed 6,3/0,4 kV transformers for low voltage supply, 6,3 kV motors and 6,3 compensation devices. The same design principles are also valid for the capacities of 6,3/0,4 kV transformers.

Low voltage motors, (Motor control Center-MCC), illumination system and low voltage compensation devices are the main loads of 0.4 kV busses.

III. VERIFICATION OF MODELING ACCURACY

At the first step of the study PETKiM power generation and distribution system described above is modeled for simulation. Accuracy and validity of modeling is tested by comparison of Dig-Silent simulation results and actual measured values for two different loading the loading conditions at 1 March 2007 14:35 and 13 April 2007 14:28, respectively. System configuration, namely connection of busses, loads, generators and TEiA§ transformers, is taken as it was in these days. All the loads besides four 6,3 kV motors which are directly fed from 34,5 kV switchgear, are assumed to be supplied from 34,5 kV buses.

Reduced system configuration up to 34.5 kV busbars for the two cases is illustrated in Figure 1.

Simulation results are tabulated in Table 1-Table 4 together with the measured values and the corresponding relative differences between the measured and the calculated values. 1 and 2 stand for the results of first case (March 1 2007) and second case (April 13, 2007) respectively. Sim. And Meas. Stand for Dig-Silent simulation and System measurements respectively.

Table 1. Comparisons of Bus Voltages

	Meas. 1	Sim. 1	Diff	Meas. 2	Sim. 2	Diff
	kV	*kV*	*%*	*kV*	*kV*	*%*
A	34,52	34,57	0,14	34,53	34,53	0,00
B	34,52	34,57	0,14	34,53	34,53	0,00
C	35,05	35,00	0,14	35,00	35,01	0,03
D	35,15	35,16	0,03	35,03	35,10	0,20

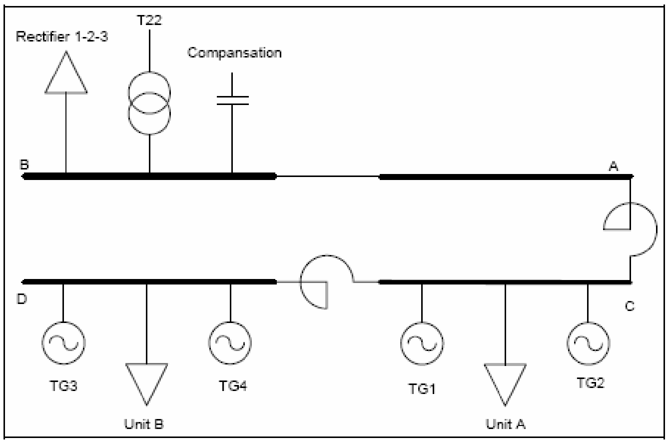

Figure (1). System Configuration in March 1 and April 3.

Table 2. Comparisons of TEiA§ transformer outputs

	Meas. 1		Sim. 1		Diff	
	P	*Q*	*P*	*Q*	AP	AQ
	MW	*MVAr*	*MW*	*MVAr*	%	%
T21	0,000	0,000	0,000	0,000	0,00	0,00
T22	-14,571	-1,789	-15,640	-1,790	7,34	0,06
	Meas. 2		**Sim. 2**		**Diff**	
	P	*Q*	*P*	*Q*	*AP*	*AQ*
	MW	*MVAr*	*MW*	*MVAr*	%	%
T21	0,000	0,000	0,000	0,000	0,00	0,00
T22	-14,589	-0,819	-12,700	0,000	12,95	100,00

Table 3. Comparison of Motor loads

	Meas. 1		Sim. 1		Diff	
	P	*Q*	*P*	*Q*	AP	*AQ*
	MW	*MVAr*	*MW*	*MVAr*	%	%
AYPE M1	5,702	1,577	5,700	1,390	0,04	11,86
AYPE M2	6,316	0,969	6,320	0,670	0,06	-
TAYPE M	7,383	-0,086	7,390	0,250	0,09	-
YYPE M	2,345	0,694	2,350	0,640	0,21	7,78
Compansation	0,058	-6,680	0,040	-6,650	31,03	-0,45
	Meas. 2		**Sim. 2**		**Diff**	
	P	*Q*	*P*	*Q*	*AP*	*AQ*
	MW	*MVAr*	*MW*	*MVAr*	%	%
AYPE M1	0,023	0,068	0,020	0,120	-	-
AYPE M2	6,379	1,103	6,380	0,780	0,02	29,28
TAYPE M	8,539	0,211	8,540	0,360	0,01	-
YYPE M	2,031	0,616	2,040	0,500	0,44	18,83
Compansation	0,035	-6,635	0,040	-6,640	14,29	0,08

Table 4. Comparison of Generator Outputs

	Meas. 1			Sim. 1			Diff		
	P	*Q*	*U*	*P*	*Q*	*U*	*hP*	*hQ*	*AU*
	MW	*MVAr*	*Kv*	*MW*	*MVAr*	*Kv*	*%*	*%*	*%*
TG1 (from 34,5 kV)	15,84	6,53	-	15,84	6,49	10,93	0,00	0,61	-
TG2 (from 34,5 kV)	48,00	24,98	-	48,00	21,19	10,96	0,00	15,17	-
TG3 (from 34,5 kV)	55,60	17,36	10,9	55,59	14,59	10,88	0,02	15,96	0,18
TG4 (from 10,5 kV)	17,90	8,80	10,74	17,90	8,67	10,78	0,00	1,48	0,37
	Meas. 2			**Sim. 2**			**Diff**		
	P	*Q*	*U*	*P*	*Q*	*U*	*hP*	*hQ*	AU
	MW	*MVAr*	*Kv*	*MW*	*MVAr*	*Kv*	*%*	*%*	*%*
TG1 (from 34,5 kV)	14,60	7,27	-	14,60	6,76	10,94	0,00	6,95	-
TG2 (from 34,5 kV)	42,81	20,84	-	42,81	20,76	10,94	0,00	0,38	-
TG3 (from 34,5 kV)	53,74	15,47	10,8	53,74	12,28	10,80	0,00	20,62	0,00
TG4 (from 10,5 kV)	18,00	8,80	10,70	18,00	8,72	10,77	0,00	0,91	0,65

Comparison results can be summarized as:

- Differences for bus voltage are less than 0,2%.
- TEiA§ active power injection errors are 7% and %13.
- 6.3 kV motor power differences are high when compared with the others.
- Generator reactive power differences are less than 20%. They can be ignored since bus voltage magnitudes are of first concern.

Voltage magnitude differences are so small that they can be ignored. The probable sources of the differences between active and reactive powers are:

- Non simultaneous measuring,
- Modeling deficiencies of the control system of several equipments,
- Differences between measuring principles of the equipments and different active and reactive power readings.

IV. SHORT CIRCUIT ANALYSIS

Short circuit simulations are conducted for the configurations explained below in accordance with IEC-60909. Each plant is represented by its equivalent motors at 6.3 kV level. Equivalent motor parameters are determined in accordance with IEC-60909/2 standard.

The first operating configuration corresponds to the case where the PETKiM generation is at its highest level. It is illustrated in Figure 2. A-C, CD and D-B busbar couplings are provided through the reactors. 6,3 kV busses A and B of the cells are fed from 34,5 kV busses C and D, respectively. Rectifier transformers and compensation cells are fed from 34,5 kV B bus. TEiAS. transformers T21 and T22 are connected to bus A and bus B, respectively. Generators TG3 and TG4 are connected to bus D and generators TG1 and TG2 are connected bus C.

The second configuration also corresponding to high PETKiM generation is illustrated in Figure 3. 6,3 kV busses A and B of the cells are fed from 34,5 kV busses C and D, respectively. Rectifier transformers and compensation units are fed from 34,5 kV B bus. An additional transformer T31 is connected to Bus A. TEiAS. transformers T21 and T22 are connected to bus A and bus B, respectively. Generator connections are the same as in first configuration.

The third configuration is the revised form of the second one and is illustrated in Figure 4. Here, AYPE T2 and AYPE M2 transformers are fed from bus B instead of Bus D. On the other hand, PETKiM generation is less than Case II and TEiAS. supply is maximized. This configuration is generally preferred during the night time when TEiAS. tariff are minimum.

The last configuration is generally not preferred for normal operating conditions. It is the revised form of the first configuration. The difference is the direct coupling between busses A and B (Figure 5).

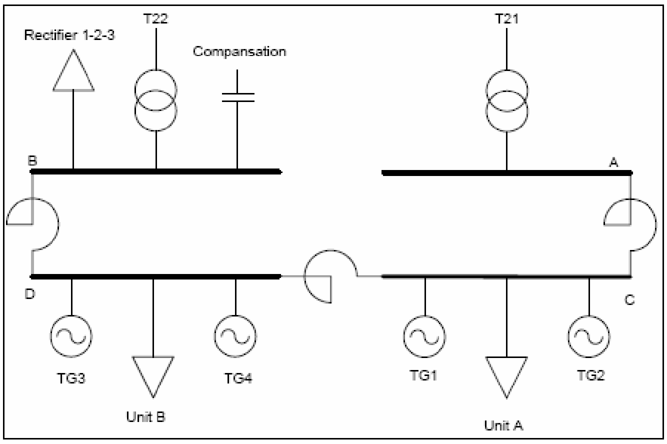

Figure (2). Simplified configuration of Case 1

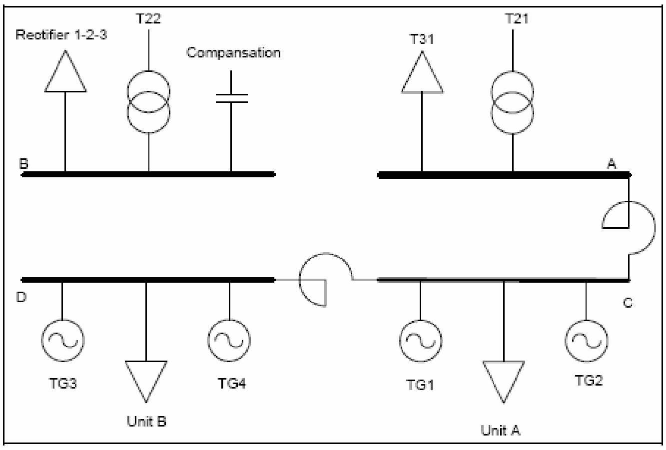

Figure (3). Simplified configuration of Case II

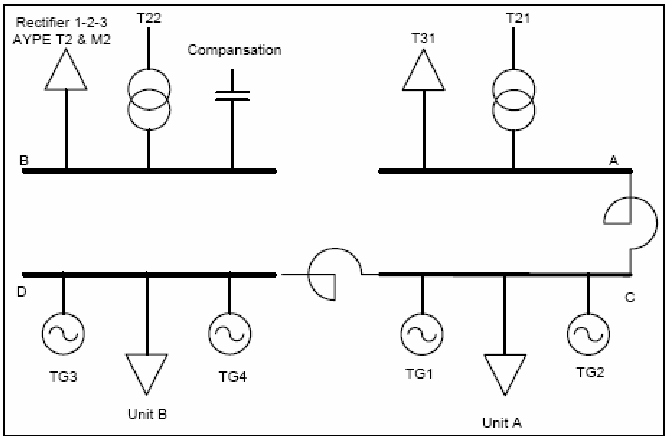

Figure (4). Simplified configuration of Case III

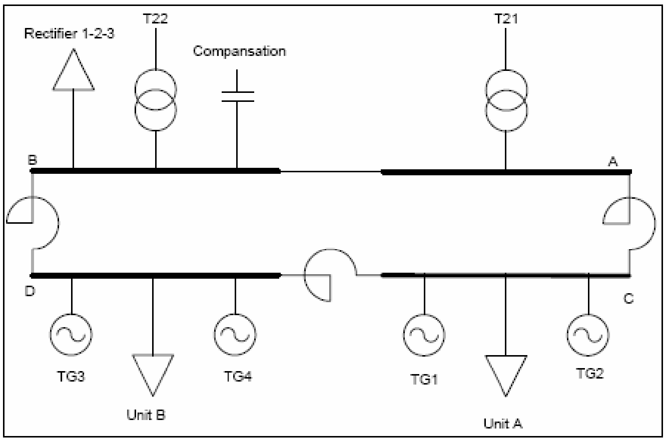

Figure (5). Simplified configuration of Case IV

Two short circuit currents are determined for each of four different operating configurations.

- Maximum short circuit currents to determine the ratings of system equipments as well as to investigate the extension possibility of the system.
- Minimum short circuit currents to determine the settings of the protective equipment.

The following assumptions are made during the calculations.

> Short circuit conditions do not change during the simulation period; it is not cleared and it does not change the type.
> The system under consideration does not change during the simulation period.
> Transformer impedances are assumed to be constant during the simulations.
> Arc resistance/reactance is not taken into consideration.
> Static loads, hat capacitances and shunt admittances are ignored accept the zero sequence reactance.
> Source voltage is assumed to be 1.1 pu and 1.0 pu for maximum short circuit current and minimum short circuit current calculations, respectively.
> All line resistances are taken at 20 ^{o}C.

Symmetric three phase short circuit simulation results and single phase short circuit simulation results are compared from the point of

- 34.5 kV busbar withstand short circuit currents,
- 6.3 kV busbar withstand short circuit currents,
- 34.5 kV relay settings,
- TEIAS relay settings,
- 34.5 kV system short circuit perception and
- Expansion possibilities of the system

to identify the best operating configuration.

V. SIMULATION RESULTS

Maximum short circuit currents of 34.5 kV systems for three phase balanced short circuit conditions and single phase short circuit conditions are illustrated in Tables 5 and 6, respectively.

Table 5. Maksimum 3ϕ Short Circuit Currents of 34.5 kV busbars[kA]

Bus	Case-I	Case-II	Case-III	Case-IV	Limit
A	16.22	16.71	16.66	27.89	**25**
B	16.18	8.00	8.86	27.89	
C	24.64	23.07	22.8	25.75	
D	24.40	19.36	18.49	25.53	

Table 6. Maksimum 1ϕ Short Circuit Currents of 34.5 kV busbars [kA]

Bus	Case-I	Case-II	Case-III	Case-IV	Limit
A	1.85	1.55	1.55	1.87	**25**
B	1.85	0.31	0.31	1.87	
C	1.86	1.56	1.56	1.87	
D	1.86	1.55	1.55	1.86	

It can easily be seen that the three phase short circuit currents of busbars C and D are near to their upper limits for all configurations. Case four is the worst one where all currents exceed their limits. This shows that the system can not be extended anymore. Since 154/35 ve 34,5/10,5 are grounded via high earthing resistances, there is not a problem for single phase short circuit currents. However, the system requires a better insulation against the overvoltages resulting due to single phase short circuits.

Maximum short circuit currents of 6.3 kV systems for three phase balanced short circuit conditions and single phase short circuit conditions are illustrated in Tables 7 and 8, respectively.

Table 7. Maximum 3ϕ Short Circuit Currents of 6.3 kV busbars[kA]

Bus	**I**	**II**	**III**	**IV**	**Limit**
AYPE-M A 6.3	21.34	21.18	21.15	21.44	**23**
AYPE-M B 6.3	21.38	20.79	17.95	21.48	**23**
Arom A 6.3	17.21	17.20	17.21	17.33	**20**
Arom B 6.3	17.17	17.11	17.11	17.50	**20**
E	22.70	21.61	21.60	22.80	**23**
F	22.68	22.06	21.93	22.78	**23**
Hava A 6.3	20.03	19.88	19.85	20.12	**23**
Hava B 6.3	22.67	22.67	21.98	22.78	**23**
PP A 6.3	18.38	18.30	18.28	18.43	**20**
PP B 6.3	16.96	16.63	16.56	17.02	**20**
PVC A 6.3	9.99	9.95	9.94	10.02	**11**
PVC B 6.3	10.71	10.55	10.51	10.71	**11**
TAYPE-M 6.0	20.16	19.61	19.49	20.25	**25**
Note that only busses having critical short circuit currents are illustrated.					

Table 8. Maksimum 1ϕ Short Circuit Currents of 6.3 kV busbars[kA]

Bus	I	II	III	IV	Limit
AYPE A 6.3	19.27	19.15	19.13	19.34	**23**
AYPE B 6.3	19.29	18.85	16.87	19.36	**23**
AYPE-M A 6.3	23.26	23.12	23.09	23.34	**23**
AYPE-M B 6.3	23.28	22.76	20.41	23.36	**23**
Arom A 6.3	17.29	17.21	17.20	17.33	**20**
Arom B 6.3	17.45	17.17	17.11	17.50	**20**
E	22.56	21.86	21.85	22.63	**23**
F	22.54	22.10	22.00	22.61	**23**
PP A 6.3	18.38	18.30	18.28	18.43	**20**
PP B 6.3	16.96	16.63	16.56	17.02	**20**
PVC A 6.3	10.36	10.32	10.32	10.38	**11**
PVC B 6.3	10.86	10.74	10.71	10.88	**11**
SkA A 6.3	19.95	19.82	19.80	20.02	**23**
SkA B 6.3	19.50	19.04	18.94	19.58	**23**
Note that only busses having critical short circuit currents are illustrated.					

There are several critical 6.3 kV busses (AYPE , AYPE-M, Arom, E, F, PP, PVC and SkA) where the three phase and single phase short circuit currents are near to their corresponding limits.

The relay settings of 34.5 kV protective devices are done with respect to minimum single phase and three phase short-circuit currents. The details of minimum short circuit currents are given in [3] and will not be reproduced here. Since 34.5/6.3 kV transformers are the transformers are **A-Y** connected, single phase faults occurring at 6.3 kV side can not be captured by the earth leakage current settings of 34.5 kV systems. The relays have two settings i.e. 0 s and 3 s delays for overcurrent protection and a single 2 s delay setting for earth leakage current protection. According to simulation results, all three phase short circuit faults are between the two overcurrent settings and are therefore be captured with a time delay. However, single phase faults at 6.3 kV side can not be captured.

According to the simulation results, minimum three phase short circuit currents and single phase short circuit currents are greater than relay settings and in all configurations TEIAS relays are capable of capturing the short circuit faults.

When a fault occurs at 34.5 kV busses, it must be captured by the relays of the sources supplying the short circuits and those sources must be disconnected from the faulted bus. Protection system of PETKIM is capable of doing it. According to simulation results, TEAS protective relays are capable of capturing 3 phase faults with a time delay of 0.15 s; but there are some problem in capturing single phase faults occurring at busses A and B.

VI. CONCLUSIONS AND SUGGESTIONS

Some suggestions and conclusions with respect to the short circuit simulations are given below:

- Three phase short circuit currents and single phase short circuit currents of several 34.5 kV busses and 6.3 kV busses are either close to or exceeding their limits. Those busses should be strengthen against electro dynamical forces.
- There are some problems in capturing single phase short circuits at 34.5 kV busses A and B. Therefore relay settings should be revised.
- There are some problems in capturing single phase short circuits at 6.3 kV busses. These problems can be alleviated by including the line portion between the transformer and the 6.3 kV bus in the differential protection zone of the transformer.
- Without and additional precautions, none of the configuration is adequate for system expansion since the short circuit currents are near to the corresponding limits.

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