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Distribution Substation Performance Improvement: Case Study

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Electric power quality is one of the most challenging topics for electrical companies throughout the world. The planning and the structure of distribution stations (DS) play an important role in the power quality and the performance of these stations. This paper studies the structure and the components of the distribution substation and presents some technical ideas in order to enhance its performance. The effect of (33/0.4) kV transformer, ONAF transformers, and power factor correction, will be discussed for higher power distribution reliability in terms of peak-load management and power delivery interruptions. The medium voltage outdoor distribution station of (33/11) kV in AL-Tur in Palestine is adopted as a case study to illustrate the proposed technical actions.

Keywords: Distribution station, Medium voltage substation, Power factor correction, ONAF transformer.

1. Introduction

The production and transmission of electricity are relatively efficient and inexpensive, however, unlike other forms of energy, electricity can not be easily stored and thus must be used as it is being produced. The electric power system consists of three main subsystems: the generation subsystem, the transmission subsystem, and the distribution subsystem. Electricity is generated at the generation station by converting a primary source of energy to electric energy. The voltage output of the generators is then stepped up to an appropriate transmission level using a step-up transformer. The transmission delivers the energy to the distribution substation where the load centers. The voltage is then stepped down to an appropriate level. The power steps down at the low-voltage distribution station that supplies the residential and commercial customers with the requiring load demands [1]-[5].

The demands for electric power and electric power quality are increasing continuously. Therefore, it is important to reduce the power losses on existing networks and it is required sometimes to make changes to the network and distribution stations for better performance. Old distribution substations are operated manually and suffer from many drawbacks and may cause many problems for the grid. On the other hand, automated DSs are becoming mandatory for achieving more reliable and stable operations under abnormal operating conditions. Power systems planners must follow the electrical standards to ensure high performance and also the continuity of supply even in abnormal conditions (maintenance, external disturbances, internal faults, component failures, and lighting strokes). Besides the reliability standards, which provide decision-making for continuity of power supply under different operation conditions, the improvements and modifications in DS can also increase the reliability of the power transmission [6].

Literature review shows that the enhancement of DS has been studied using different approaches and methodologies. Some researchers concentrate on the interruption and continuity of power supply, therefore they concentrate on analyzing the fault occurrence

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and determining its location [7], [8]. Using computers in monitoring and control the power system elements leads to a huge data collection of the network and its parameters. These data need specific algorithms to be manipulated and treated optimally to reduce the computation based on it, and how it can be used efficiently to improve the performance of the DS [9], [10]. Many researchers in the last decade are focusing on smart grids and how they can be managed, i.e. solving the location of different distributed generators, to reduce the grid losses and improve the reliability [11]-[14]. In [15] ABB researchers present a comparative study on outdoor distribution devices, such as line re-closers, automatic sectionalises, and manual switches, that can improve network reliability. Researchers in [16] discussed the improving performance of underground distribution networks using an automation system. In [17] the reliability of the distribution substation is enhanced by using network reconfiguration.

This paper proposes using some technical ideas that can lead to enhancing the DS performance and increasing its reliability. The first technique is power factor correction; this technique is trivial but important to enhance the DS performance. The second method is studying reconfiguration of the DS by using 33/0.4 kV instead of using 33/11 kV and 11/0.4 kV. The third technique discusses the increase of DS capacity due to the replacement of transformer type, i.e. using of ONAF transformer. To illustrate the efficiency of the proposed techniques a real medium-voltage 33/11 kV DS data are used as a case study.

To the best of the authors' knowledge, considering a case study to highlight the proposed techniques for improving the DS is innovative and not presented in the literature. The major contributions of this research are summarized as follows:

- Reduce the voltage drop and losses in the distribution feeders,
- Study the effect of power factor improvement on the DS,
- Investigate the performance of DG by reconfiguring the transformer voltage level, and
- Increase the DS capacity by replacing of ONAN transformer with ONAF.

The paper is organized as follows: after the introduction and the literature review in Section 1, introduce the case study description and operation in Section 2. Section 3 presents the three technical ideas which are proposed to improve the performance of the DS. Conclusion remarks and recommendations are given in Section 4.

2. Case Study Description (Al-Tur DS)

AL-Tur is a neighborhood in Jerusalem Governorate located east of Jerusalem City. The elevation of AL-Tur is 826 meters above sea level, the average annual humidity is approximately 61%, and the average annual temperature is 17 C. AL-Tur has a total area of around 16.3 km^2, the population of AL-Tur had reached 27,000. The station center is located in the coordination of (220652, 637304) at the north of AL-Tur in Jerusalem and has an area of 200 square meters. Distribution systems serve as the link from the distribution substation to the customer. Typical distribution systems begin as the medium-voltage three-phase circuit and terminate at a lower secondary three- or single-phase voltage at the customer’s premise. Jerusalem District Electricity Company (JDECO) started to deliver the generated power through a distribution network owned by the JDECO. The delivered electric power increased in the last years due to the normal modernization and industrialization increase.

2.1 AL-Tur DS Components

Th substation receives electrical power at 33 kV from one source and delivers power at 11kV. The electrical power is fed to small industries and domestic loads in and around of AL-Tur neighborhood. The components of the DS are listed in Table1.

Table 1. Specifications and components of the DS

AL-Tur substation components	
33 kV Switchgears	11kV Voltage Transformer Auxiliary
11 kV Switchgears	AC Supply Panel Earthing System
33 kV Current Transformers	Lightning Protection System
33 kV Voltage Transformer	Incoming Supply Cable 300 mm2 Aluminium
33 kV Surge Arresters	Metering units
11 kV Current Transformers	Two of 15MVA Power transformers

The transformers are installed outdoor, and according to its nameplate, it has the following parameters: power rating: 15MVA for each transformer, voltage rating: 33kV/11kV, transformer impedance: Z% it is the voltage drop in full load due to winding resistance and leakage reactance expressed as a percentage of rated voltage, the station's transformer impedance is 10.097%. Winding connection: dyn11 connection, insulation: the station's transformer is based on oil insulation. Insulation levels of the transformers: LI200 AC 70 at high voltage side / LI96 AC 20 at low voltage side, cooling: the station employs the ONAN (Oil-Natural-Air-Natural) principle. Voltage regulator: taps can be automatically changed so that regulation can be done without interrupting the load. 8. Buchholz Relay: to protect the transformer from failure and used in liquid insulation type transformer.

2.2. Connection Topology

The neighborhood of AL-Tur is supplied with electric power from a main substation of the Israel Electric Company (IEC), where the voltage is stepped down from 33 kV to 11 kV. The single line diagram of the AL-Tur substation is shown in Fig.1. It is important to mention that the coupling between (Bus A 11 kV) and (Bus B 11kV) is important for emergency and faulty cases. Therefore, if one of the main two suppliers has been interrupted on the side of 11 kV, then the circuit breaker between them will be closed to support the interrupted zone if and only if the load is within the capacity of the remaining transformer.

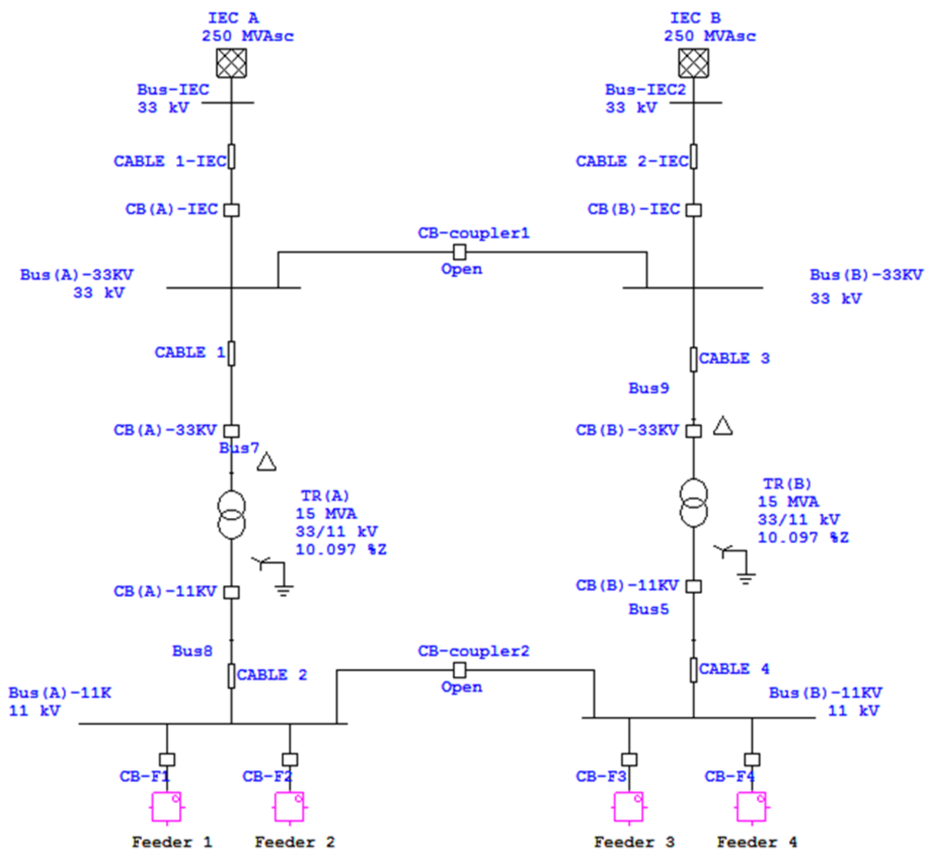

Fig.1: The single line diagram of AL-Tur substation modeled by ETAP software

2.3. Power losses in Transmission lines

Cable power losses are due to the conductor resistance heating that occurs when current flows. These cable losses are more often called I²R losses or kW losses. This is expressed by Eq. (1).

$$\Delta P = 3\, I^2 R \qquad (1)$$

For a group of sections on feeder, the total power losses can be calculated by using Eq. (2) [18].

$$\Delta P = 3 \sum_{K=1}^{N} I_k^2 R_{o_k} L_k \qquad (2)$$

Where, ΔP = Total of power losses of the feeder in Watt, I = Magnitude of the cable current, L = Length of the cable in km, Ro = Resistance of the cable conductor per length in Ω/km, N = Number of cables of the feeder. For example, the total power losses on feeder 4 can be calculated as follows:

$$\Delta P = 3\Big\{\Big((169.2A)^2 \times 0.098\frac{\Omega}{km} \times 1.105km\Big) + \Big((157.7A)^2 \times 0.161\frac{\Omega}{km} \times 0.361km\Big) + \Big((145.7A)^2 \times 0.098\frac{\Omega}{km} \times 0.495km\Big) + \Big((123A)^2 \times 0.196\frac{\Omega}{km} \times 0.228km\Big) + \Big((110.5A)^2 \times 0.325\frac{\Omega}{km} \times 0.284km\Big) + \Big((82.7A)^2 \times 0.196\frac{\Omega}{km} \times 0.275km\Big) + \Big((60.7A)^2 \times 0.325\frac{\Omega}{km} \times 0.118km\Big) + \Big((42.3A)^2 \times 0.411\frac{\Omega}{km} \times 0.593km\Big) + ((31.8A)^2 \times 0.247\ \Omega/km \times 0.164km) + ((13.7A)^2 \times 0.568\ \Omega/km \times 0.498km)\Big\}$$

ΔP =25kW

The simulation was done using ETAP (Electrical Transient Analyser Program) software. Table A-1 in Appendix A shows the losses through all feeders of AL-Tur DS. The total losses through all the feeders are equal to 108.886 kW.

According to JDECO Company/SCADA for AL-Tur substation loads, the operating power factor normally ranges from 82% to 87%. Table A-2 in Appendix A displays the load flow simulation for the DS with the power factor for each load.

3. Substation Improvements

This section discusses the different ways of improvement that can be done to the system in order to increase its efficiency, decrease the interruptions' times and deliver the best service to consumers.

3.1 Power Factor Improvement

Improvement of the power factor of an installation presents several technical and economic advantages, notably in the reduction of electricity bills. The installation of a capacitor bank to improve the power factor is one of the cheapest methods of correcting power lag problems. Using a capacitor bank in the power supply system effectively cancels out or counteracts these phase shifts issues, making the power supply far more efficient and cost-effective. Because of the importance of the power factor on the economic performance of the grids, several new methods and researches are applied to improve the power factor [19]-[21]. The installation of power factor correction equipment on installations permits the consumer to reduce his electricity bill by maintaining the level of reactive-power consumption below a value contractually agreed with the power supply authority. The IEC Company recommended a power factor of 90% for high voltage substations, and if the power factor is less than 90% the quantity of reactive energy is billed by additional rate. The required value of reactive power to improve the power factor can be calculated using Eq. (3) [22],

$$Q_C = P\,(\tan\varphi - \tan\grave{\varphi}) \tag{3}$$

where, QC = the value of required reactive power for the improvement in kVAR., P = Total real power of the load in kW, φ = Phase shift between voltage and current before correction, $\grave{\varphi}$ = Phase shift between voltage and current before correction.
The power factor is defined as the ratio of active power (kW) to apparent power (kVA):

$$P.F = cos\varphi = \frac{P}{S} \tag{4}$$

The given data for the case study, on side A, the average real power consumption is 2790 kW, and the average apparent power is 3338 kVA. While on side B, the average real power consumption is 6393 kW, and the average apparent power is 7752 kVA. According to the IEC standard (60871), the power factor for high voltage substations must be 0.90 [22], [23]. The phase shift angle after correction, $\acute{\varphi} = \cos^{-1} 0.90 = 25.84°$.
.
The required value of reactive power QC of the capacitor bank:

$$Q_{C_A} = P\,(tan\varphi_A - tan\acute{\varphi}) \qquad Q_{C_B} = P\,(tan\varphi_B - tan\acute{\varphi})$$

$$Q_{C_A} = 2790\,(tan33.28 - tan25.84) \qquad Q_{C_B} = 6393\,(tan34.41 - tan25.84)$$

$$Q_{C_A} = 480\ kVAR \qquad Q_{C_B} = 1283\ kVAR$$

However, this calculated value of reactive power cannot be found exactly because capacitor banks are available in standard values. Tables 2 and 3 show the effect of power factor improvement on the grid. Results show that the reactive power is reduced by 1734 kVAR, which means a reduction in the billing. Correction of power factor increase in the DS capacity where the current is reduced by 38 A (i.e. 7.11%), which means also a reduction of power losses, P(losses)= I^2 R.

Table 2: Power consumption of AL-TUR substation before P.F. Correction

	P[kW]	cosθ	Q[kVAR]	I [A]	S[kVA]
TR1	2783	84.5%	1759	174.5	3292
TR2	6370	84.8%	3978	408.3	7510
Total (TR1+TR2)	9153	---	5737	---	10802

Table 3: Power consumption of AL-TUR substation after P.F. Correction

	P[kW]	cosθ	Q[kVAR]	I [A]	S[kVA]
TR1	2783	91.0%	1266	161.7	3057
TR2	6366	91.9%	2737	373.1	6930
Total (TR1+TR2)	9149	---	4003	---	9987

3.2 Replacement of 33/11 kV and 11/0.4 kV Transformers by 33/0.4 kV Transformer

To solve the voltage drop and losses in transmission lines, some researchers suggest using a bank of capacitors to reduce the voltage drop as in [24]. In the Al-TUR substation, to deliver the power to the consumers with 0.4kV two levels of transformers (33kV to 11kV) and from (11kV to 0.4kV) are used. Between the two transformers, there are losses in the feeders because of the resistance of the transmission cables expressed by I2R, and we noticed that the losses of Al-Tur feeders were 89.623 kW as Table A-3 in Appendix A. Thus we study the option of replacing these two-level transformers with one-level transformers of 33/0.4 kW. Calculating the feeders' losses shows that it was reduced from about 90kW to 8 kW.

If we do a simple calculation of the impact of this reduction of losses,

$kW\ saving\ per\ year = (90kW - 8kW) \times 24H \times 365 = 718320\ kW$.h

If we consider that 1kW.h cost 0.41 NIS, then

$saving\ money\ per\ year = 718320kW.h \times 0.41\ NIS \approx 300{,}000\ NIS/year \approx 92{,}300\ USD/year$

Besides the above operation saving costs, the power factor of the substation also has been improved at side A from 84.5% to 85.6%, and at side B it has been improved from 84.8% to 88.3%. Also, we noticed that the low voltage at the consumers' side has been improved from 373 V to 393 V.

3.3 Increase the Substation Capacity by Reconfiguring the Transformer Cooling System

Several types of research are done on the performance of the transformers with increasing temperatures [25]-[30]. All of these researches concluded that increasing the temperature has a bad effect on the transformer performance. Therefore, substation transformers of 15 MVA and larger typically have multiple capacity ratings, such as 9.4/11.7/14.7 MVA, which correspond to different cooling classes, such as ONAN/ONAF/OFAF, (ONAN: Oil Nature Air Nature, ONAF: Oil Nature Air Forced, OFAF: Oil Forced Air Forced). In this substation, the lowest rating of the 15MVA transformer can supply 9.4MVA only which represents the self-cooled transformer capacity and has the ONAN cooling class rating. The rating of 11.7 MVA, is the capacity of the transformer when it uses fans to force air through the oil cooler radiators; this rating has the ONAN/ONAF cooling class rating. The next rating, 14.7 MVA has the rating ONAN/ONAF/ONAF cooling class rating, which is an abbreviation for Liquid-immersed, self-cooled/forced air-cooled/forced air-cooled. Same as ONAN/ONAF with an additional set of fans. There typically will be three load ratings corresponding to each increment of cooling. Increased ratings are obtained by increasing cooling air over portions of the cooling surfaces. Typically, there are radiators attached to the tank to aid in cooling. The two groups of fans may be wired to start automatically at pre-set levels as temperature increases. There are no oil pumps. Oil flow through the transformer windings is by the natural principle of convection.

In our case study, the power-station transformers work on the ONAN mode, as the power consumed in each transformer is 3336 kVA and 7750 kVA, respectively. However, with a malfunction in one of the main transformers and the coupler busbar circuit breaker is activated to feed loads of the faulty transformer, then the transformer that will carry all the load will be overloaded and will not bear more than a few hours. So to improve this behaviour, external fans are used to run the transformer in the ONAN/ONAF or a group of fans to operate on the ONAN/ONAF/ONAF mode. Thus, in this case, the capacity of each transformer increased from 9.4 KVA to 14.7 KVA adding no additional transformer.

In operation of the transformer on the ONAN mode, and one transformer carries all the feeders, then it will be overloaded, which cannot bear more than a few hours, also it has been noted the voltage on the busbar has fallen to 10.4kV. However, if we operate the transformer on the ONAN/ONAF/ONAF mode, and when one transformer carries all the feeders, then it will NOT be overloaded, but instead there will be 3.6 MVA extra spare-power transformer capacity available. In addition, it has been noted the voltage on the busbar has been improved to 10.6kV instead of 10.4kV

4. Conclusion

The paper highlighted some important features (power factor, transformer rating, and cooling system of transformer) and how they can improve the performance of the DS. Power design and planning engineers could also consider these features in their future planning. A real medium-voltage 33/11 kV case study is considered investigating the effect of these features on performing the DS. Results show that the correction of power will reduce the current by 7.11% and will reduce the billing of 1734 kVAR and power losses. Replacement of 33/11 kV and 11/0.4 kV transformers by 33/0.4 kV will reduce the losses from 90 kW to 8 kW which means saving around 92 k USD / year. Reconfiguring the transformer's cooling system based on our case study will spare 3.6 MVA and could easily control the power flow through one transformer if the second transformer is faulty.

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Appendix A

Table A-1: Feeders power analysis and losses

ID	Rating 1	kW Flow	kvar Flow	Amp Flow	% Loading	kW Losses
CABLE 1	25 m	2788	1835	58.47	8.4	0.019
CABLE 1-IEC	4000 m	2788	1833	58.45	8.4	2.925
CABLE 2	25 m	2784	1760	175.4	25.1	0.174
CABLE 2-IEC	4000 m	6391	4384	136.1	19.5	16.338
CABLE 3	25 m	6391	4386	136.1	19.5	0.105
CABLE 4	25 m	6371	3979	408.3	58.4	0.942
F1-CABLE1	128 m	1443	940	91.74	22	0.604
F1-CABLE2	202 m	1140	749	72.72	17.4	0.599
F1-CABLE3	72 m	971	634	61.83	19.1	0.256
F1-CABLE4	185 m	836	554	53.5	16.5	0.492
F1-CABLE5	79 m	293	209	19.22	5.9	0.027
F2-CABLE1	81 m	1340	820	83.71	22.9	0.43
F2-CABLE2	234 m	953	594	59.88	16.4	0.635
F2-CABLE3	169 m	549	330	34.13	9.3	0.149
F2-CABLE4	236 m	132	74.469	8.106	1.7	0.007

F3-CABLE01	816 m	3747	2305	239.2	38.7	13.098
F3-CABLE02	393 m	3462	2123	221.8	68.4	17.968
F3-CABLE03	235 m	3023	1857	194.7	60.1	8.277
F3-CABLE04	345 m	2967	1827	191.7	52.1	8.96
F3-CABLE05	310 m	174	115	11.52	4	0.048
F3-CABLE06	218 m	2525	1555	163.6	39.2	3.274
F3-CABLE08	601 m	1833	1128	118.9	28.5	4.769
F3-CABLE09	310 m	496	316	32.48	8.9	0.247
F3-CABLE10	210 m	235	156	15.6	3.2	0.023
F3-CABLE11	283 m	198	112	12.62	2.6	0.021
F3-CABLE12	403 m	1357	846	88.6	21.2	1.776
F3-CABLE13	202 m	1002	614	65.17	22.9	1.008
F3-CABLE14	294 m	812	494	52.76	18.5	0.962
F3-CABLE15	317 m	710	429	46.12	11	0.378
F3-CABLE16	256 m	444	270	28.93	10.1	0.251
F3-CABLE17	265 m	169	95.242	10.79	2.9	0.023
F4-CABLE1	1105 m	2623	1673	169.2	27.4	8.88
F4-CABLE2	361 m	2433	1556	157.7	32.7	4.134
F4-CABLE3	495 m	2243	1438	145.7	23.6	2.951
F4-CABLE4	228 m	1880	1225	123	29.5	1.934
F4-CABLE5	284 m	1687	1100	110.5	34.1	3.222
F4-CABLE6	275 m	1260	822	82.67	19.8	1.055
F4-CABLE7	118 m	916	614	60.67	18.7	0.404
F4-CABLE8	593 m	634	438	42.45	14.9	1.252
F4-CABLE9	164 m	474	328	31.8	8.6	0.117
F4-CABLE10	498 m	205	142	13.74	5.7	0.152
Total Losses						***108.886***

Table A-2: AL-Tur loads flow simulation with power factor

ID	Rating	kW Flow	kvar Flow	Amp Flow	% PF	% Loading
TR(A)	33 / 11 kV	2788	1835	58.47	83.53	35.4
TR(B)	33 / 11 kV	6391	4386	136.1	82.45	82.2
F1-TR1	11 / 0.4 kV	302	192	19.08	84.45	90.4
F1-TR2	11 / 0.4 kV	169	115	10.9	82.51	81.4
F1-TR3	11 / 0.4 kV	135	81.079	8.381	85.66	62.6
F1-TR4A	11 / 0.4 kV	256	168	16.33	83.54	77.3
F1-TR4B	11 / 0.4 kV	287	178	17.99	84.98	85.1
F1-TR5	11 / 0.4 kV	293	209	19.22	81.49	91
F2-TR1	11 / 0.4 kV	386	228	23.9	86.07	71.4
F2-TR2	11 / 0.4 kV	405	265	25.79	83.64	77
F2-TR3	11 / 0.4 kV	416	257	26.08	85.11	77.9
F2-TR4	11 / 0.4 kV	132	74.469	8.106	87.17	60.5
F3-TR1	11 / 0.4 kV	272	172	17.55	84.53	81.1
F3-TR2	11 / 0.4 kV	421	261	27.19	84.98	78.9
F3-TR3	11 / 0.4 kV	48.34	27.852	3.069	86.65	55.2

F3-TR5	11 / 0.4 kV	174	115	11.52	83.57	66.5
F3-TR6	11 / 0.4 kV	194	112	12.37	86.57	56.5
F3-TR7	11 / 0.4 kV	260	161	16.93	85	77.3
F3-TR9	11 / 0.4 kV	272	173	17.86	84.45	81.4
F3-TR10	11 / 0.4 kV	198	112	12.62	87.07	90.8
F3-TR11	11 / 0.4 kV	354	233	23.51	83.5	67.5
F3-TR12	11 / 0.4 kV	189	121	12.45	84.25	71.4
F3-TR13	11 / 0.4 kV	101	67.881	6.751	82.92	48.4
F3-TR14	11 / 0.4 kV	265	160	17.23	85.56	78.2
F3-TR15	11 / 0.4 kV	275	177	18.21	84.17	82.6
F3-TR16	11 / 0.4 kV	169	95.242	10.79	87.1	77.2
F3-TR17	11 / 0.4 kV	258	156	16.63	85.48	76.1
F3-TR18	11 / 0.4 kV	235	156	15.6	83.37	71.3
F4-TR1	11 / 0.4 kV	181	115	11.72	84.48	85.5
F4-TR2	11 / 0.4 kV	186	118	12.05	84.53	87.7
F4-TR3	11 / 0.4 kV	360	213	22.91	86.05	66.6
F4-TR4	11 / 0.4 kV	191	126	12.53	83.44	57.7
F4-TR5	11 / 0.4 kV	424	278	27.86	83.57	80.7
F4-TR6	11 / 0.4 kV	343	208	22.07	85.44	63.9
F4-TR7	11 / 0.4 kV	281	180	18.36	84.15	84.3
F4-TR8	11 / 0.4 kV	160	110	10.68	82.34	77.2
F4-TR9	11 / 0.4 kV	270	189	18.15	81.9	83.1
F4-TR10	11 / 0.4 kV	205	142	13.74	82.13	62.9

Table A-3: Cables losses comparison before and after swapping transformers with 33/0.4 kV

ID	Rating 1	kW losses before swap TRs	kW losses after swap TRs
CABLE 1	25 m	0.019	0
CABLE 2	25 m	0.174	0
CABLE 3	25 m	0.105	0
CABLE 4	25 m	0.942	0
F1-CABLE1	128 m	0.604	0.064
F1-CABLE2	202 m	0.599	0.063
F1-CABLE3	72 m	0.256	0.027
F1-CABLE4	185 m	0.492	0.052
F1-CABLE5	79 m	0.027	0.003
F2-CABLE1	81 m	0.43	0.027
F2-CABLE2	234 m	0.635	0.067
F2-CABLE3	169 m	0.149	0.016
F2-CABLE4	236 m	0.007	0.001
F3-CABLE01	816 m	13.098	1.232
F3-CABLE02	393 m	17.968	1.695
F3-CABLE03	235 m	8.277	0.776

F3-CABLE04	345 m	8.96	0.843
F3-CABLE05	310 m	0.048	0.005
F3-CABLE06	218 m	3.274	0.307
F3-CABLE08	601 m	4.769	0.447
F3-CABLE09	310 m	0.247	0.024
F3-CABLE10	210 m	0.023	0.002
F3-CABLE11	283 m	0.021	0.002
F3-CABLE12	403 m	1.776	0.168
F3-CABLE13	202 m	1.008	0.095
F3-CABLE14	294 m	0.962	0.09
F3-CABLE15	317 m	0.378	0.036
F3-CABLE16	256 m	0.251	0.024
F3-CABLE17	265 m	0.023	0.002
F4-CABLE1	1105 m	8.88	0.843
F4-CABLE2	361 m	4.134	0.397
F4-CABLE3	495 m	2.951	0.285
F4-CABLE4	228 m	1.934	0.187
F4-CABLE5	284 m	3.222	0.311
F4-CABLE6	275 m	1.055	0.101
F4-CABLE7	118 m	0.404	0.038
F4-CABLE8	593 m	1.252	0.119
F4-CABLE9	164 m	0.117	0.011
F4-CABLE10	498 m	0.152	0.015