

Analysis of a gas station hybridization with a solar thermal plant by using ETAP

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ABSTRACT

Iraq is facing deficiency of electric power for last decades. The main reason for deficiency of electric power is due to less respect of analytical load flow studies of electric supply substation. To stop and overcome such situation in future, researchers should be analyzing different power substation focusing on load flow studies, short circuit studies and protection schemes. Due to lack of research and studies on load flow and fault analysis, Iraq is facing a lot of issues, such as power failures and high copper losses, solving of these problems on substation level, demand a high familiarity about the power system. In this paper we analyses combined typical gas station with solar thermal power station and survey load flow, short circuit, transient stability, and voltage drop before and after combined station by using electrical transient analyzer program (ETAP). Now a day's power supply reliability and goodness are big interest. analyses of power system are a main part in power system designing and planning, in order to accommodate future loads and the expansion of cities.

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1. INTRODUCTION

Iraq has a lack in the sector generation of electricity over 6500 MW growing in the season summer on account of the heavy want to use cooling devices in this hot season from year, that begun from the month May to the end of the September. Iraq should employ solar irradiation to generate the electric to cover the big lack as one of its aims as part of its emphasis to decreasing environmental harm and dirtiness of the country's weather, water, and the soil and searching to find good methods to employ green energy in the Iraq. Solar energy is a clean energy which has the possible to meet a big proportional of the world's energy needs. Obtainability of solar irradiation resources in Iraq, as well as to being eco-friendly, is the main reason to realize the choice of this resource of energy. We see that solar irradiations energy in this country covers each of these demands. Our country Iraq is distinguished by some factors like amount of sunny hours in the year and it is evaluated more 3400 h, as well as, the irradiation in Iraq more than 2300 kWh/m² [1, 2]. Fossil fuel (oil, gas, etc) is finite which require the need to research internal for a sustainable and eco-friendly ways of production electric.

The improvement in the solar technologies in the last years, as production of electric by using solar energy has modern the interest in the thermal solar for electric production. However, because of a big quantity of heat lost over start up and shut down the power plant, and rising cost of saving heat energy during the absence of the sun, in addition height technical and economic risk, it application has been limited and has

given rise to the introduction of hybrid solar system. In this paper, we suggested the system of Integrated Solar combined cycle system (ISCCS) as a method of combining parabolic trough solar collectors field with combined cycle plants for the goal of enhancing the cost and efficiency of the system. Now, in 2020, Iraq yet suffers from many shortages in the supply of the electric to the people, despite of more 80% of the manufactories and government buildings are not working. The request for power electric in this country raised from 11500 MW in the 2007 to the 16500 MW in the 2013, to the 24500 MW in the summer 2018, and is predictable that the demand for electricity will be raised by more than 33000 MW in the 2022. Around 70% of the total electricity generated in 2013 are loosed, which contains both technical, commercial and administrative losses transmission 6%, distribution 13%; theft and no billed 23%; no collected 26%; and collected 33% [3-5]. Over 90% of the losses are in the distribution network of which 79% are non-technical losses (theft, no billed and no collected). The distribution system generally is in miserable structure and seems to be one of the tightness in the electricity feeding, as it is deformed by incompetent administration and shortage of investment. The absolute and unplanned growth, in addition to the old age of the grid, have led to heavy loading and suffering from rise technical and no technical losses. The use of new technology and good planning has a large direct effect in reducing losses. In this paper we see that the absence of planning is one of the main causes of electrical energy losses. Short circuit, voltage steadiness and load flow analyses are every time needed for suitable installation, steady and reliable running, and safety schema settings of the power plant. And these itemized analyses allow input of any system that may be wanted in the future for expansion and enhancement for this system. We will be doing a survey for one gas power plant in southern Iraq with part of electrical grid from Al-Basra city.

The power station design is a plant of gas turbine system with ability 200 MW lying in Al-Basrah province, we will be combining two steam turbines with ability 75 MW at high pressure, and the second with ability 65 MW at low pressure, with reheater and the economizer [3-11]. We chose this station for two reasons, firstly, for its distinguished location in Al-Basra city, where it is located outside the city and surrounded by large empty spaces, as the city is considered the best Iraqi city with the amount of solar radiation during the year, which makes it distinct to establish a thermal station next to it and the use of empty spaces to install solar reflectors to operate the auxiliary heat station. The second reason is the problems that the network suffers from lack of energy and voltage drop, which allows us to conduct a survey by using program electrical transient analyzer program (ETAP). We will submit the station to a survey in a program ETAP before and after adding the thermal station in order to know the size of the changes that occur on the network and how we can address the problems of low voltages and power factor as the program allows us to determine the areas of weakness in the network and the way of resolve by optimal capacitor placement (OCP) [6]. The analyses of power flow, the voltage constancy, and the short circuit are constantly wanted for adequate composition, steady and reliable operation system, and safety scheme settings of any electric power system.

2. RESEARCH METHOD

The plant contains 200 MW conventional gas turbine plant contains four units 50 MW per one, and connected with two power steam turbines with an ability of 75 MW and 65 MW fed by a big solar field and power gas turbine exhaust [11-16]. With more insolation in the season of the summer, the month of June the station can obtain over 25% of the solar part by ISCCS station. In this paper, we describe the electrical power system of a 340 MW ISCCS by using the program ETAP and its power flow analysis. We study and simulate the changes at network before and after adding the thermal station and load flow calculations in both cases. So, down-voltage buses are fixed and their voltages are recovered as to the required pre-set voltage area, by using on-load tap changer regulation (OLTC) and OCP. The electrical system of a 340 MW ISCCS having 4 gas turbine plants and connected with two steam turbine plants. The 4 gas stations are generated 50 MW per one, and the steam power plants produce 65 MW and 75 MW, and all are linked to the main bus is called (Khur Zubair), each generator is linked to the central bus by its step-up transformer and is generating power at 20 kV voltage standard then raised to 132 kV. The main bus (Khur Zubair) connected with step-up transformers a raised voltage level to 400 kV to send the surplus power to the national grid by 2 three-winding transformers with 250 MVA per one. The main bus (Khur Zubair) fed eight main loads (steel factory 22 MW, Fao 21.6 MW, bab Zubair 20.5 MW, Rumaila field 80 MW, Um-Qaser city and the port 220 MW, the Zubair oil field 45 MW, Albaker port 20 MW, the center city 110 MW) most of the loads are consumed in the oil fields, factories and ports, as the deficit is met by the national network [5, 7]. We designed the simulation of the system by helping program ETAP, and then implement the desired analyses at two situations before and after combined gas station with a solar thermal power station.

3. CONSIDERED CASES

3.1. Case 1: Current situation

As we mentioned previously, the station in the current situation consists of 4 gas units and a capacity of 50 MW per unit and a total capacity of 200 MW to feed the national grid. The network in the current situation suffers from several problems, the most important of which is the voltage drop and the permanent outage. As the station is no longer able to secure the need for loads on the network, therefore the deficit is imported from the national network.

3.1.1. Load flow for case 1

The power flow analysis of station by utilizing program ETAP can see in Figure. 1. The famous method called (The Newton-Raphson method) is used to analyze the load flow noted that the buses 121, Rumaila, and Um qaser, and their branches there is an under voltage standard, which can be obviously seen from Figure 1. Table 1 shows the main feeders with the main buses, which has a big voltage drops.

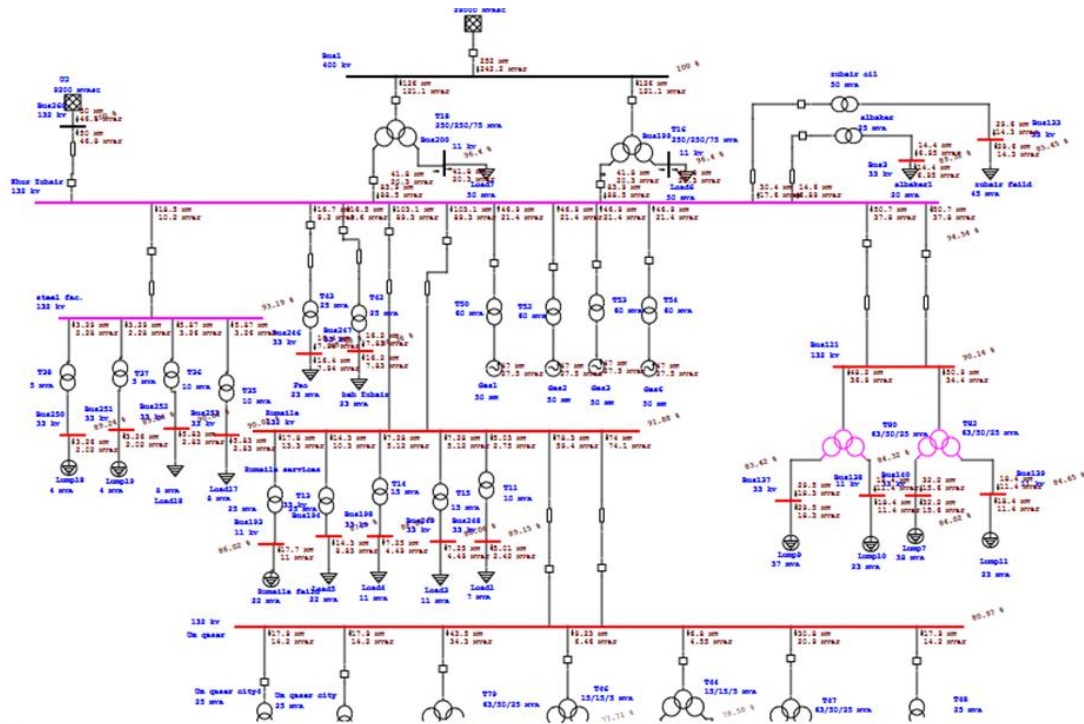


Figure 1. Single diagram for system at case1

Table 1. Results of load flow

ID bus	Voltage		From network		load	
	Nom.V	%mag.	MW	Mvar	MW	Mvar
1 swing	400	100	252.011	242.194	0	0
260	132	100	50.000	46.765	0	0
121	132	88.8	0	0	101.4	75.6
Rumaila	132	86.5	0	0	206.2	178.6
Um-Qaser	132	80.4	0	0	152.3	133.5

3.1.2. Short circuit analysis for case 1

Analysis of short circuit is used for determine the max and min 3 phase faults for all types at each bus when fault make and fault break situations inclusive the DC element. The kinds of short circuit are line to ground (L-G), line to line (L-L), two lines to earth (LL-G), three lines (L-L-L) and three lines to ground (L-L-L-G) fault [16-18]. The standard of IEC 60909 short circuit fault in all systems of 3 phase, describes an internationally acceptable way for the computation of all fault currents types. The following Table 2 is the results of short circuit analysis at the main bus Khur Zubair with nominal voltage 132 kV and voltage c factor 1.10.

Table 2. Analyses of short circuit for all types at main bus

Type of short circuit fault	Three phase	LG	LL	LLG
Initial symmetrical current in kA, rms	29.114	27.165	25.264	28.405
Peak current (kA), method C	75.530	70.474	65.542	73.691
Breaking current (kA, rms, symm)	-	27.165	25.264	28.405
Steady state current (kA, rms)	25.160	27.165	25.264	28.405

3.1.3. Transient stability analysis

Definition of the system reply due to various troubles which are the source of instability i.e., which due to waste of synchronism or stopping or overloading of motors and generators. Transients switching are usually linked with breakdown of breakers and switches, or turning of capacitor banks and other repeatedly switched loads. In this paper show the instability of system when loose one of its loads (Um-Qaser) look at the Figures 2 and 3 illustrated the power angle and speed of the generators:

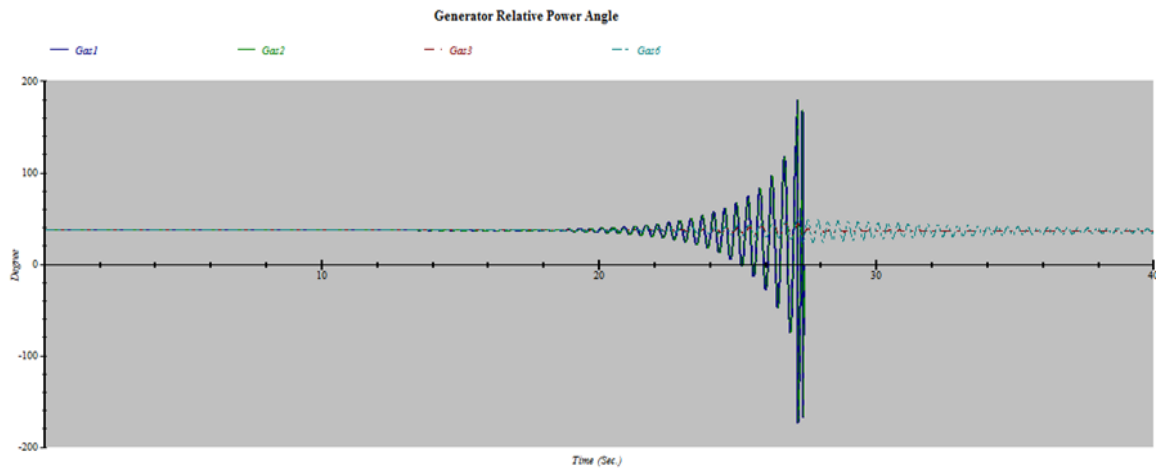


Figure 2. Power angle

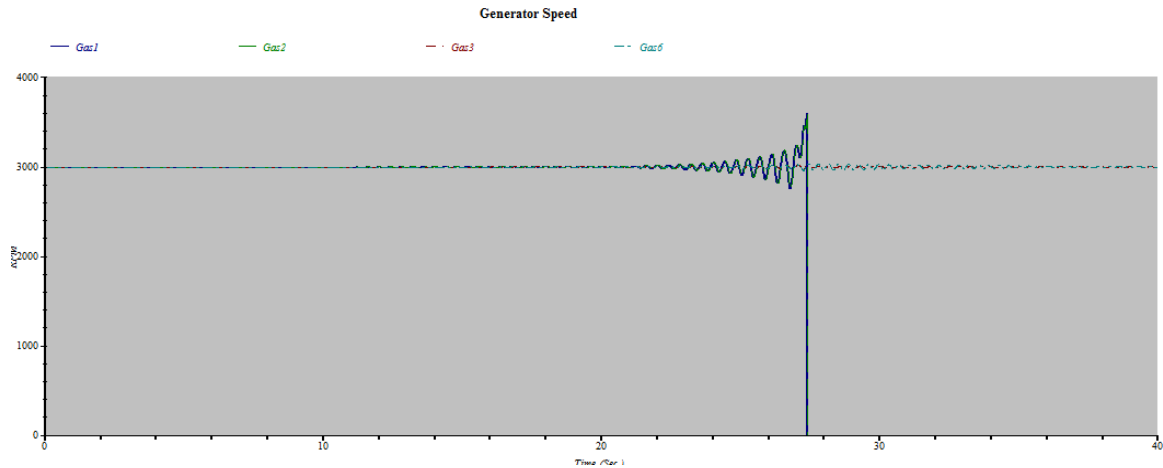


Figure 3. Generator speed

3.2. Case 2: After combined with solar thermal station

In this case, we will be adding (75 MW and 65 MW steam turbines) operated with the solar field collectors and the gas exhaust from gas power plants of 200 MW. With high irradiation in the season of summer during the month of June the station can be achieved more than 25% of the solar part when using the ISCCS station [3].

3.2.1. Load flow for case 2

The load flow analysis of station at case 2 combined gas power plants with solar thermal station with 130 MW by utilizing program ETAP is shown in Figure. 4. The major purpose of the analysis load flow is definition of the steady state, reactive and active flow power, flow of current, power factor and voltage profiles for system (quantities, angles of load and generator bus voltages) [19-24]. Figure 4 analysis of the load flow of a ISCCS and it is clear that the voltage drop was fixed in most of the network except the bus Um-Qaser was at under voltage we will explain all changes in Table 3.

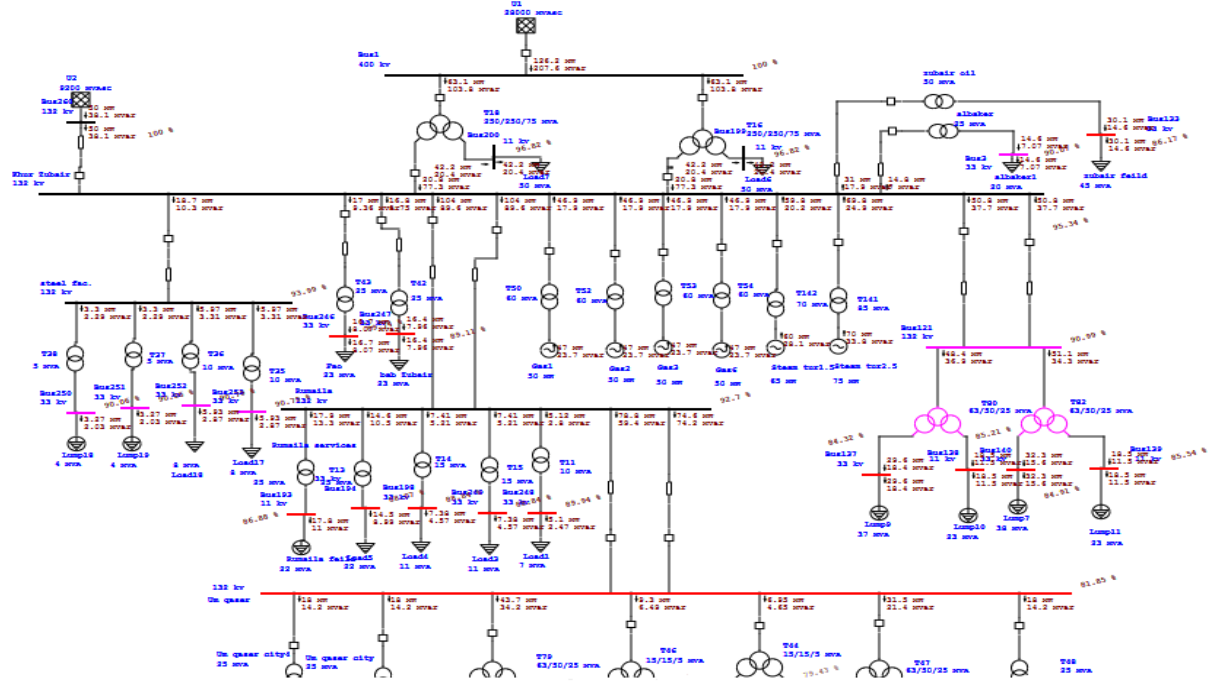


Figure 4. Load low at case

Table 3. Results of load flow at case 2

ID bus	Voltage		From network		load	
	Nom.V	Mag.%	MW	Mvar	MW	Mvar
1 swing	400	100	126.2	207.6	0	0
260	132	100	50	38.1	0	0
121	132	91	0	0	101.6	75.4
Rumaia	132	92.7	0	0	208	179.2
Um qaser	132	81.85	0	0	153.4	133.6

3.2.2. Short circuit analysis for case

By using ETAP features we get new information after combined gas station, and Table 4 show us the new data about short circuit.

Table 4. Analysis of short circuit

Type of short circuit	Three phase	LG	LL	LLG
Initial symmetrical current in kA, rms	31.554	28.553	27.410	30.460
Peak current (kA), method C	82.059	74.253	71.281	79.212
Breaking current kA, rms, symm	-	28.553	27.410	30.460
Steady state current (kA, rms)	27.641	28.553	27.410	30.460

3.2.3. Transient stability analysis for case 2

We repeat the same experience that we had on the system in the first case to ensure the stability of the system or not. By viewing the Figures 5 and 6, it becomes clear to us that the system is in a stable state.

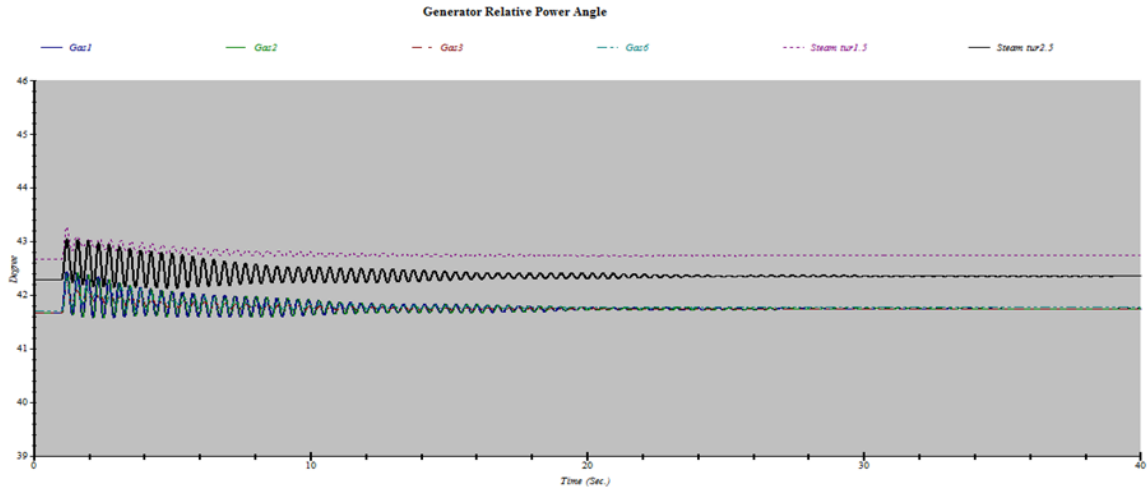


Figure 5. Power angle

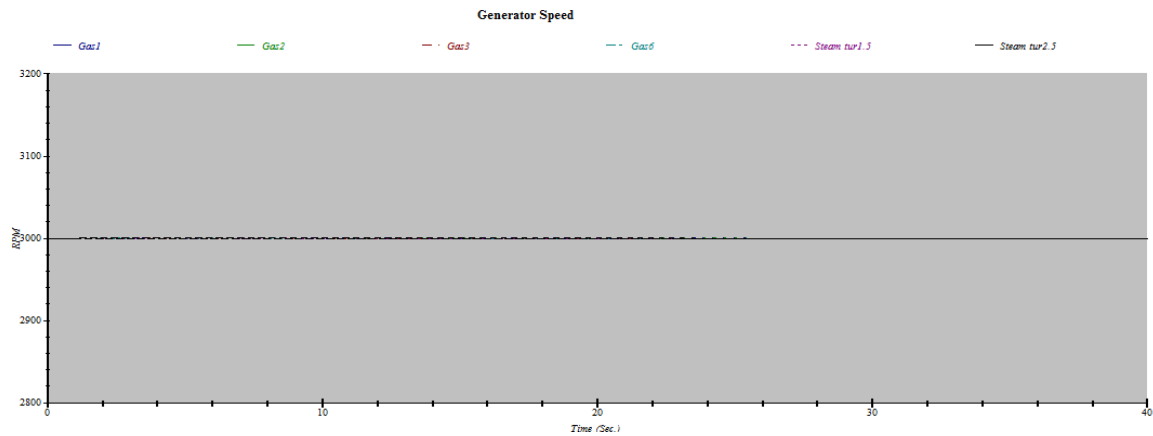


Figure 6. Generator speed

4. STABILITY VOLTAGE IMPROVEMENT BY OCP

System has an under voltage over 20% is integrated in network, from this problem, the voltage on some weak buses is minimized and to recover this under voltage by using OLTC integrated with transformers are employed. But from their area is just $\pm 10\%$, voltage at many buses is yet under 90%. To get better voltage for these buses optimal capacitor placement (OCP) function of ETAP is utilized. The input variables are entering for the study case of the (OCP) function. These contain the voltage limitations, elected buses to improvement their voltages and estimated of ready capacitor banks. The voltage limitation is fixed to $90\% \leq V \leq 115\%$ and it is universal to each system buses. The results after doing OCP function in Figure 7 and Table 5. ETAP uses genetic algorithm technique for OCP [25-27]. The main aim of the (OCP) is to minimize the cost of the system and these costs include 4 parameters and can be represented mathematically in this formula:

$$M_{in} \text{ objective function} = \sum_{i=1}^{N_{bus}} (x_i C_{0i} + Q_{ci} C_{1i} + B_i C_{2i} T) + C_2 \sum_{i=1}^{N_{load}} Tl P_L^l \quad (1)$$

The main parameters cost are: Cost of fixed capacitor installation, cost of capacitor purchase, cost of capacitor bank operating (maintenance and depreciation), and real power losses cost. To clarify more, we compare the information obtained from studying at two cases (before and after combined with solar thermal station). Look at Table 6 illustrate the comparison between the two cases throws the candidate buses.

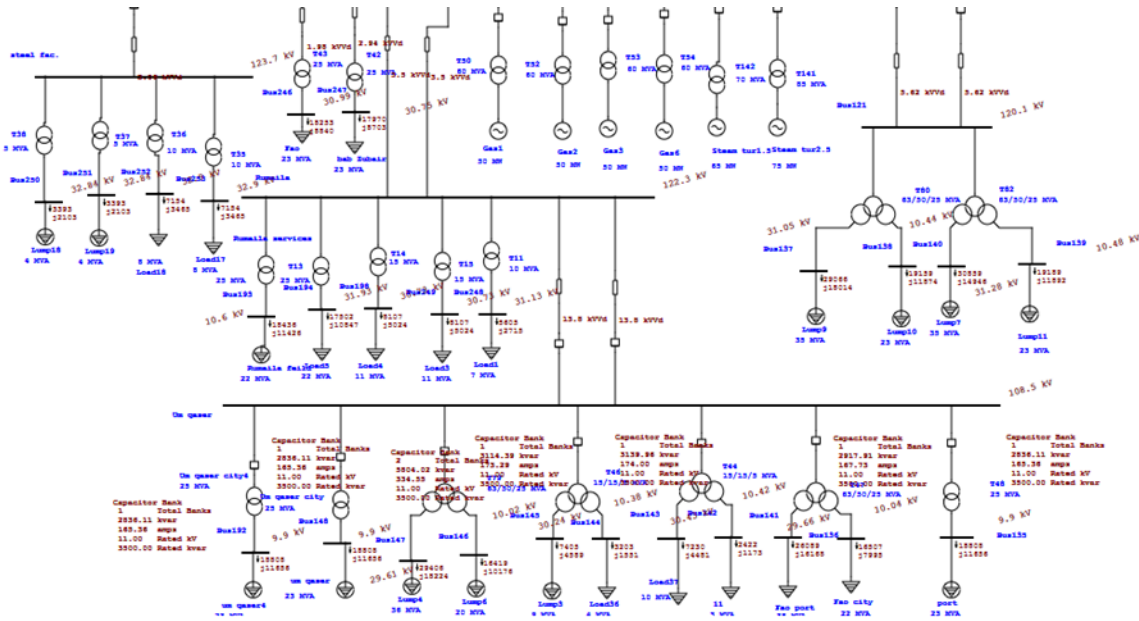


Figure 7. Single diagram for system after OCP

Table 5. Results enhancement voltage by OCP

ID bus	Nom. kV	% Mag.	PF%	No banks	Rated kvar/Bank	Operated kvar
135	11	90.018	90.5	1	3500	2800
136	11	91.306	90.5	1	3500	2917
138	11	94.870	90.5	-	-	-
139	11	95.272	91	-	-	-
142	11	94.717	90.5	1	3500	3139
144	11	94.331	92	1	3500	3114
146	11	91.057	90.5	2	7000	5800
148	11	90.018	90.7	1	3500	2836
192	11	90.018	91	1	3500	2836

Table 6. Comparison between results of two cases

ID bus	Case 1				Case 2			
	MW	Mvar	V%	PF%	MW	Mvar	V%	PF%
1 (swing)	252.011	242.194	100	100	126.2	207.6	100	100
135	17.7	14.2	76.2	79	18.8	11.6	90.018	90.5
148	17.2	14.2	76.5	80.4	18.9	11.3	90.018	90.7
192	17.8	14.2	77	80.5	18.8	11.6	90.018	91

5. CONCLUSIONS

Iraq enjoy very good solarly, ranking from 1,900 to 2,410 kWh/m²/year of irradiation, many of the free flatlands is suitable for an ISCCS station. After combined gas plant to ISCCS its efficiency could be reaching to 55%, when it is 20-80% more than at conventional gas plants. The major advantage, of ISCCS station are fuel economy, the decrease of the electric needed at the peak time and the decrease of CO₂ releases. Rebuilding all traditional stations like (gas and steam power stations) and converting to the ISCCS power stations, it will decrease trillions of tons of CO₂ release and economize a high quantity of barrels of fuel equivalent yearly, all that due to economize trillions \$ through the life-time of the station. In this paper we discussed and analytical station with part of the national network in southern Iraq by using ETAP. And we divided our survey into two cases, in the first case, we dealt with the gas station alone and the amount of problems in the network from system instability, power losses, and voltage drop. It is clear from Table 1 the main buses operated at under voltage (Um-Qaser, Rumaila, bus 121) to improve voltage by OLTC not more ±10%, so, stay the same problem because the voltage drop at some buses over 20%. From the same table show the power draw from the national grid (252.011+J242.194). The test of transient stability shows us the system instable. From the Table 6 show us the comparison between the candidate buses at two cases, we are

getting benefits from our survey that we can to observe and analyze the power system exactly, resolve the under-voltage problem at all load buses, extend the substations in future power request, recover the power factor of all buses in power system, and reduce the losses at more buses in power system.

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