Journal of Engineering and Sustainable Development
https://jeasd.uomustansiriyah.edu.iq/index.php/jeasd
https://doi.org/10.31272/jeasd.27.1.1

Vol. 27, No. 01, January 2023
ISSN 2520-0917

Original Research

SIMULATION OF OPERATION PUMP –STATION WATER IN IRAQ AND CHALLENGES FACING ITS OPERATION WITH POWER SYSTEM

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Received 31/10/2022 ***Accepted in revised form 29/12/2022*** ***Published 1/1/2023***

Abstract: This research focuses on real problems that suffer from pump stations during their connection with the national electric network, in our paper, we will take negative effects that appear in the pump stations with power flow parameters, voltage, active and reactive power current loading, and total losses. Using an electric network have 28 Buses (test2) as a simulation of Iraq's electric network. Firstly, we will connect a pump station has a capacity of power equal to 75 MVA and do an analysis by the Neplan program which uses the Newton Raphson method to calculate load flow, after that we are solving problems by using FACT'S system (SVC, UPFC, and capacitor bank). also taken the problem of power equality as the effect of Harmonic which produced from electronic devices "soft start of the pump station and method treatment by passive filter first order. At last, we are studying the effect of fault current and how to reduce the effect by using the Current Limiting Reactor (CLR).

Keywords: *Power flow analysis; power quality; harmonic effect & short circuit analysis; FACT'S system; program (NEPLAN), 220/110/6.6 kV substation*

1. Introduction

By studying the research and articles mentioned below, the necessity of studying the flow of active and reactive power and the levels of voltage and current in power transmission lines and improving them in many ways has been emphasized because of its great impact on the sustainability of the work of industrial loads for the longest possible period, especially synchronous motors because we need to stability about power flow parameters, the Scientific literature wide worldly taken this field and continuous depending on the conditions and requirements of the work where note some studies work through compensation reactive power, which suggests a distributed voltage control in electricity distribution networks Whereas, the researcher's strategy included maintaining the voltages of the main buses, and through them, with the help of the communication system, the adjacent buses are controlled to ensure the stability of the reactive power [15]. The change in electric power networks recently works to produce capacitive reactive power transfer from low-voltage networks to high-voltage networks which affects reactive power in transmission lines and the level of voltage in buses by controlling of admittance of transmission lines [16]. Works are focusing on a reactive power compensation technique to identify system voltage convergence rates by locating FACT'S in an effective area as

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efficiently as possible. The goal of this study is to increase the stability of the pump station and determine the best location for installing dynamic SVC sources inside our system, the impact of FACTS controllers on the reactive power compensation, which aids in voltage recovery, new insights are offered. The development of the control function and compensation technique to maintain the system's voltage within predetermined limits [17]. Much of the recent literature, especially that deals with the analysis of power networks and improving their performance using Facts systems, uses analysis software such as (Etab, Neplan, and DIgSILENT), we are focused on Neplan software to compare with our work and different networks. Some literature deals with the use of the UPFC system in their countries' networks and shows how to stabilize the system and reduce losses by 70%. [18]. The presence of electronic equipment in the control systems and the operation of pumping stations work to generate harmonics, which are transmitted to the power transmission system. Where according to IEEE 519 standards [19]. Within the limit value of THD, less than 2.5% harmonics must be reduced to maintain good grid quality. This study provides a thorough analysis of each of the concerned, obligations and the appropriate criteria for the most popular types of filters in this situation. The pursuit of a system with high work stability necessitates that we study the challenges facing the operation of synchronous machines in pumping stations, and among these challenges is the study of the fault current behaviour and ways to reduce its impact on the system, where a series file connection with fault impedance was simulated, which increases the network impedance in the face of fault current, which represents last part, which focuses on symmetric short circuit current what has a higher effect on electric equipment.

2. Details of Electric Network

Our electric network test 2 variant matches to information and nominal data of the Electric network test [1]. With the modifying number of generators, buses, transmission lines, and loads, the test 2 variant have six power plant its power generation equals 2856 MVA, with a total load equal to 1570.66 MVA, shown in Figure (1). Our electricity network has 28 buses, at 220 kV side have 14 busbars, the major high voltage buses connect between them by single circuit transmission lines. The power plant RO1 is taken as the SLACK bus, and the buses (2,5,7,10,13) PV buses represent generations of buses connected with buses of load (1,3,4,6,8,9,11,14) by transmission lines. With pump station have a capacity equal to 75MVA transmission lines.

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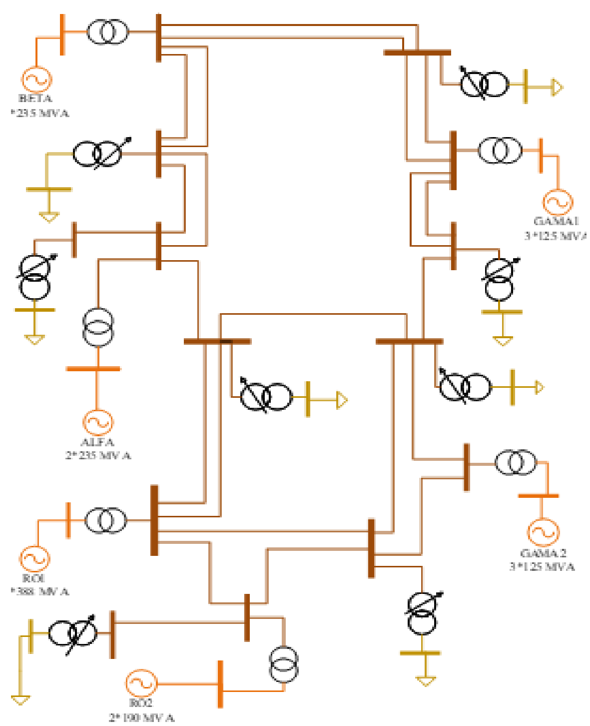


Figure 1. Single line diagram of the electric network.

3. Type of Buses

A bus is a point in which one or many transmission lines, loads, and generators are linked between them.

3.1. Slack Bus

This is used as a reference bus in command to meet the power equilibrium state. A slack bus is generally a generating unit that can be adjusted to take up whatever is wanted to verify the power balanced [1].

3.2. Generator (PV) Bus

This is a voltage regulator bus. The bus is linked to a generator part in which output power generated by this bus can be controlled by regulating the prime mover and the voltage can be controlled by adjusting the excitation of the generator [6].

3.3. Load (PQ) Bus

This is a non-generator bus that can be got from data histories, measurements, or estimates.

4. Problem statement

4.1. Power Flow

Load flow is a significant instrument used by power engineers for design, to determine the best operation for an electrical network and exchange of power between utility companies. The first step in performance load flow analysis is to form the Y-bus entrance using the transmission line and transformer input data [1]. The nodal calculation for a power system network using a Y bus can be written as follows. I=$Y_{BUS}V$ the nodal equation can be written in a generalized form for an n bus system. [3]

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \qquad \text{For i = 1, 2, 3,} n$$

$$P_i + jQ_i = V_i I_i^* \; ; \; I_i = \frac{P_i + jQ_i}{V_i} \qquad (1)$$

$$\frac{P_i + jQ_i}{V_i} = V_i \sum_{j=1}^{n} Y_{ij} - \sum_{j=1}^{n} Y_{ij} V_j \quad j = 1$$

The equation uses iterative methods to solve load flow problems.in Neplan analysis using Newton Raphson [6].

4.2. Harmonic's Effect

As the harmonic currents generated by the operators' apparatus flow back on the way to the power source, they cause additional voltage distortion due to impedance related to various power distribution apparatus, such as transmission and distribution lines, transformers, cables, and busbars [11]. Since inductive reactance is linearly relative to frequency, especially high-order harmonic currents source severe voltage distortion levels with small current amplitudes [12].

4.2.1 Electrical quantities for a non-sinusoidal condition: -

$$v(t) = \sqrt{2} \; . \; (V_1 + \sum_{=2}^{\infty} V_n \; . \; \sin(\mathrm{n} w_1 \mathrm{t} + \theta_n))$$

$$i(t) = \sqrt{2} \; . \; (i_1 + \sum_{=2}^{\infty} i_n \; . \; \sin(\mathrm{n} w_1 \mathrm{t} + \delta_n)) \qquad (2)$$

Where Vn and In are the active values of voltage and current for the nth harmonic level, respectively [1]. $\boldsymbol{\theta_n}$ And $\boldsymbol{\delta_n}$are respectively phase angles of voltage and current for the nth harmonic component for a reference angle. ω1=2πf1 [2] is the angular frequency of the fundamental frequency f1.

4.3. Analysis of short circuit current

A fault is an abnormal or unpremeditated joining of live elements of an electrical network to each other or the earth. The impedance of such connections is often very low, resulting in large currents flowing [3]. The energy contained in fault currents can quickly heat components, creates excessive forces, and can result in devastating explosions of equipment. Typically, we deal with three types of faults:

- Three Phase Faults
- Phase to Phase Faults
- Earth Faults

Typically, the highest fault current is given by a three-phase fault which we will concentrate on it [8].

4.3.1 Current Limiting Reactor (CLR)

The CLR introduces higher impedance to the system by series–connected reactance to protect the equipment during fault conditions [9]. It reduces short circuit levels to meet the system needs as well as stresses on buses, insulators, circuit breakers, and other high-voltage devices. It is, sometimes, connected between the neutral of the system and the earth for limiting the phase-to-earth current under system fault conditions [7]. It is also used as load sharing reactor for balancing the current in parallel circuits.

5. FACT'S System

5.1. Static Var Compensator (SVC)

The Static Var Compensator (SVC) is a device of the Flexible AC Transmission Systems (FACTS) family to control power flow on power grids using power electronics. The SVC regulates the voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system [5].

5.2. Unified Power Flow Controller (UPFC)

The unified power flow controller (UPFC) realizes real-time control over power flow in transmission lines by adjusting the line parameters, including node voltages, phase angle, and line impedance, which cover all adaptable parameters of other FACTS [4].

6. Case Studies

6.1. Part I Case study (1):

In the first part of our research and after building the network without a power transformer by the Neplan program, our simulation can calculate the parameters of the power flow and note the below points. As shown in Figure (2).

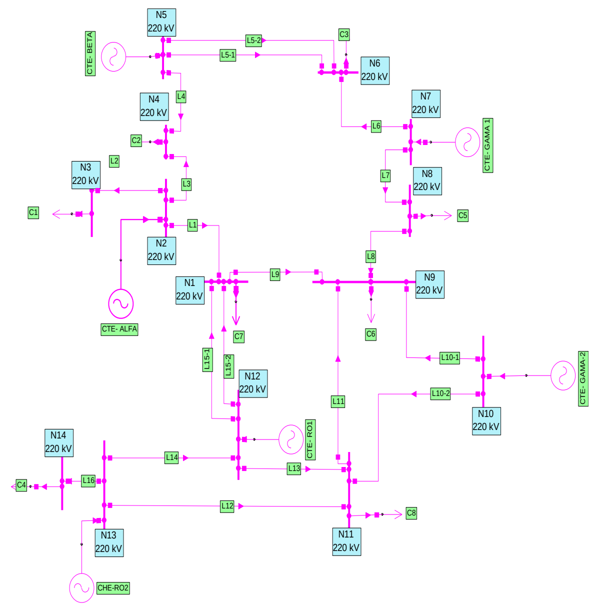


Figure 2. Single line diagram of the network with transformer by Neplan program.

- The generated voltage value is 100% because it depends on the speed of the generators which is within the synchronous speed also the DC field excitation is 100% and the power factor of the load.

- All buses have their voltage magnitude within acceptable drop voltage, where the voltage drop for AC networks should total not more than ∓10% under full load shown in Table (1), the drop voltage which represents the difference voltage between buses is directly proportional to the impedance of lines and active and reactive current pass through the lines.
- The difference in voltage phasor angles between the sending voltage and receiving voltage in all buses into the network is less than 15 degrees as shown in table (1) & chart

(1), within a controllable voltage zone, Generally, The difference in voltage phasor angles is directly proportional to smaller drop voltage between buses relative to

$$tan\,\theta = \frac{XI_a - RI_r}{V_n} \quad (3)$$

- Reactive power flow across the network is determined by the difference in the voltage phasor magnitude between buses and the susceptance of lines.
- Active power losses in the transmission line represent the difference in active power value between buses, which are supposed to be small cording to the impedance of lines and the current passing it through shown in table (2) & chart (2), In this case, the amount of reactive power produced by transmission lines becomes greater than the amount of reactive power absorbed by the reactance

$$.\ Q_{\circ}=3\,(WCV^2\text{-}WLI^2) \quad (4)$$

From the result of the Neplan program, we get these charts and tables

Table 1. Results voltage of buses 220 kV without transformers.

Name	U KV	U %	U angle °
N1	216.717	98.51	-1.9
N10	220	100	4.1
N11	214.051	97.3	-0.6
N12	220	100	0
N13	220	100	1.6
N14	214.435	97.47	-0.5
N2	194.926	88.6	-11.3
N3	188.555	85.71	-13.7
N4	187.692	85.31	-15.3
N5	204.31	92.87	-11.2
N6	201.749	91.7	-11.9
N7	220	100	-4.8
N8	208.461	94.76	-6.8
N9	206.263	93.76	-4.5

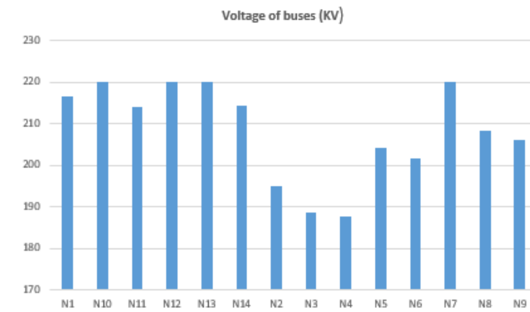


Chart 1. Results voltage of buses 220 kV.

Table 2. Results of active and reactive power of transmission lines without transformers.

Name	type	P MW	Q MVAr	I KA	Angle °	Loading %	P Loss MW	Q Loss MVAr
L9	Line	74.932	55.554	0.249	-38.5	30.87	1.0833	-2.8362
L15-2	Line	-104.929	-46.345	0.306	154.3	34.92	0.6132	-34.7894
L10 -1	Line	114.62	28.621	0.31	-9.9	35.43	2.9594	0.5026
L10-2	Line	125.38	19.63	0.333	-4.8	38.06	1.7899	0.45
L11	Line	65.698	18.119	0.184	-16	21.01	0.8585	-9.4417
L15-1	Line	105.542	11.555	0.279	-6.2	31.84	0.6132	-34.7894
L14	Line	-38.35	1.27	0.101	-178.1	11.51	0.1724	-10.0816
L13	Line	31.954	50.201	0.156	-57.5	17.85	0.2921	-5.4066
L12	Line	60.961	26.214	0.174	-21.7	19.9	0.5162	-7.3122
L16	Line	-65	-35	0.199	151.2	22.72	0.5158	-6.0289
L1	Line	-120.693	-48.895	0.386	146.6	44.08	4.2332	8.2404
L2	Line	-60	-35	0.213	136	24.31	0.5944	-3.5139
L4	Line	-130.711	-106.148	0.518	125.6	59.19	3.1494	12.6269
L3	Line	-59.289	-23.852	0.197	142.8	22.47	0.8093	-6.443
L5-1	Line	-52.889	-51.892	0.212	123.7	24.23	0.1809	-21.2791
L5-2	Line	-52.889	-51.892	0.212	123.7	24.23	0.1809	-21.2791
L6	Line	-154.222	-66.216	0.48	144.9	59.66	4.4993	14.8164
L7	Line	81.278	88.572	0.315	-52.3	36.05	1.2548	-0.0783
L8	Line	-49.976	18.65	0.148	-166.4	16.88	0.3718	-7.28

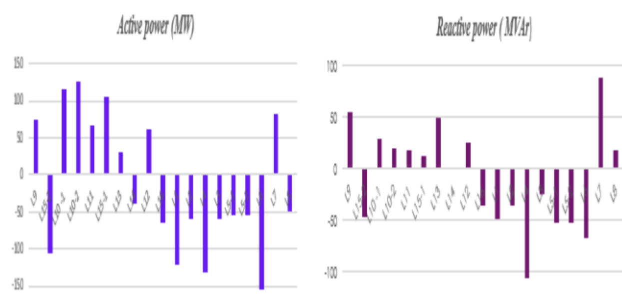


Chart 2. Result of active & reactive power flow in transmission lines.

Load Flow converged after 7 iterations. From tables (1&2) we calculated: -

Network MW losses = 24.688130

Network MVAr losses = -133.923581

And draw charts(1&2).

6.2. Part I Case study (2):

A second case from a scenario of power flow represents adding the power transformers with the absence effect of the Tap changer into our system. The type of these transformers will be:

- Step-up transformers are connected to generators.
- Step-down transformers are connected to the loads. We can show that in Figure (3).

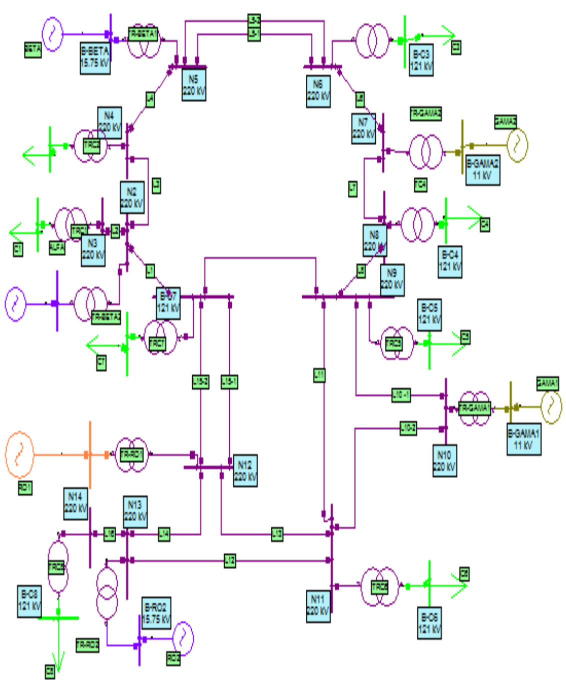


Figure 3. Single line diagram of the electrical network with power transformer absence Tap changer.

Also can note the power flow doesn't converge with the analysis of Neplan because of the increased impedance of the network which leads to voltage collapse relative to Z_{Tot}=Z_{BUSi}+Z_{LINE}+Z_{BUSk}+Z_{Tr} $\Delta V = I * Z_{Tot}$. Effect of the fixed part of Tr $Q_{\circ} = \sqrt{3}\, U_n I_{\circ}$ which represents the reactive power depending on no load current that is proportional to the square of the apparent power flow $Q = u_{sc}\frac{S^2}{S_n}$; Q_t= $Q_{\circ} + Q$. [1]

increasing reactive power without regulation voltage inside the network leads to a voltage collapse at the buses of center load (1,3,4,5,6,7,8,9) and also buses of generation as shown chats, because the increase series impedance of a system between buses after connecting transformers with absence tap changer, where that leads to increase the total impedance of the path between buses thus increase drop voltage where relative to Z_{Tot}=Z_{BUSi}+Z_{LINE}+Z_{BUSk}+Z_{Tr} [10]. Where it becomes greater than the impedance of the center load, which leads to increased power losses. We can note that the above explains in Table (3) also charts (3,4&5) to compare the status with &without transformers.

Table 3. Results voltage of buses after connecting power transformers with absence Tap changer

Name	U KV	U %	U angle °	Name	U KV	U %	U angle °
N1	212.409	96.55	-4.1	B-ALFA	14.847	94.27	4.1
N10	229.488	104.31	2	B-BETA	13.501	85.72	1.8
N11	218.622	99.37	-2.5	B-C1	108.178	89.4	-3.5
N12	222.451	101.11	-2.2	B-C2	91.937	75.98	-10.4
N13	230.219	104.65	-0.9	B-C3	97.109	80.26	-10.1
N14	224.375	101.99	-2.8	B-C4	97.423	80.52	-10.1
N2	217.797	99	0.5	B-C5	96.843	80.04	-11.5
N3	211.704	96.23	-1.4	B-C6	109.346	90.37	-6.4
N4	186.75	84.89	-5.9	B-C7	100.328	82.92	-11.6
N5	193.851	88.11	-3.6	B-C8	114.948	95	-4.9
N6	189.973	86.35	-4.7	B-GAMA1	11	100	6.7
N7	207.855	94.48	-0.3	B-GAMA2	10.119	91.99	5.3
N8	198.003	90	-4.6	B-RO1	24	100	0
N9	202.307	91.96	-5.2	B-RO2	15.75	100	2.1

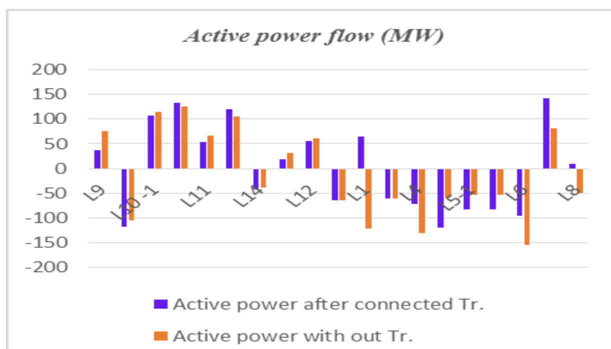


Chart 3. Results of Active power before and after connecting Tr with absence Tap Changer.

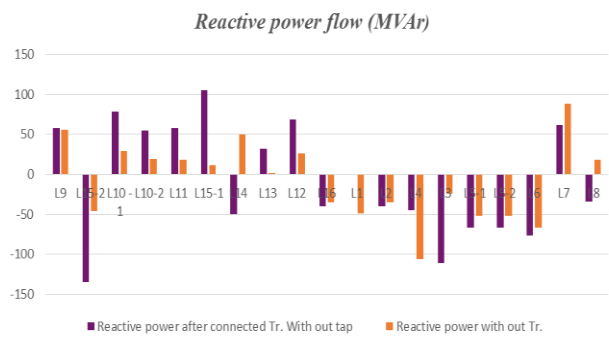


Chart 4. Results of Reactive power before and after connecting Tr with absence Tap Changer.

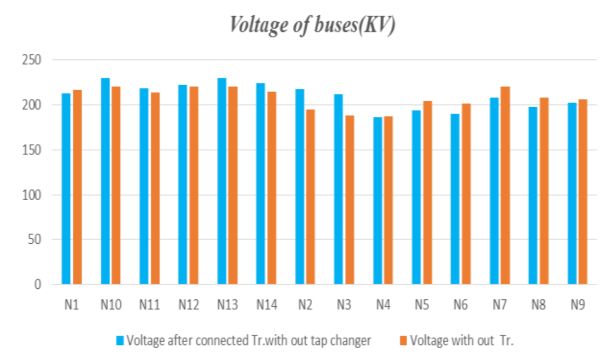


Chart 5. Results of voltage before and after connecting Tr with absence Tap Changer.

The power flow doesn't converge with the case of adding Tr as an absent Tap changer. that situation leads to a voltage collapse relative to

$Z_{Tot} = Z_{BUSi} + Z_{LINE} + Z_{BUSk} + Z_{Tr}$

$\Delta V = I * Z_{Tot}$

3.1. Part I Case Study (3): Power Tr with Operate Tap Changer

From the scenario of power flow represented by the present power Tr. By operating Tap Changer into our network. figure (4).

- The power flow has converged in 18 iterations.
- improving in the level of voltages at most buses due to the connecting Tr with the present Tap change relatively to $\Delta V = \frac{RP_\circ + X_{Q_\circ}}{N_r V_2}$ [1] note table (4) &chart (6)
- The voltage drop decrease and voltage increase are dominant which leads to a decrease in reactive power flow relative to $\Delta V \approx \frac{X_{Q_\circ}}{V_2}$ we can note table (5) &charts (7,8).

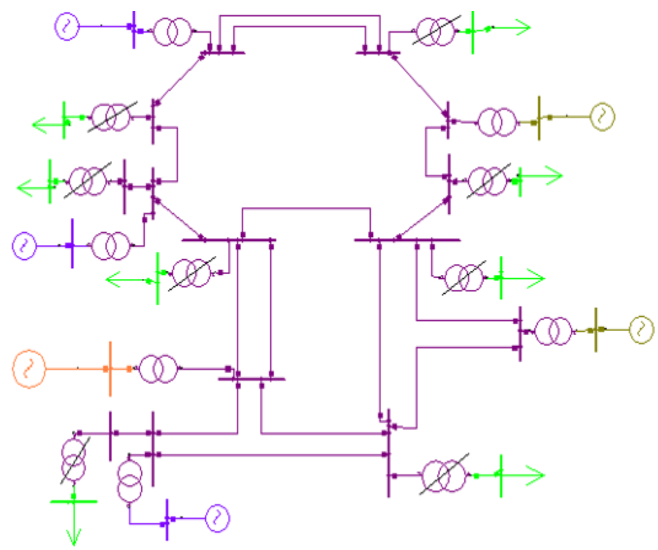


Figure 4. Network with power transformers and operating Tap changer.

Table 4. Results voltage of buses after connecting transformers with present Tap changer.

Name	U KV	U %	U angle °	Name	U KV	U %	U angle °
N1	217.691	98.95	-4	B-ALFA	15.655	99.39	3.2
N10	231.788	105.36	2	B-BETA	14.705	93.36	0.7
N11	221.989	100.9	-2.5	B-C1	116.848	96.57	-3.6
N12	225.277	102.4	-2.2	B-C2	120.609	99.68	-8.5
N13	231.862	105.39	-0.8	B-C3	120.464	99.56	-8.5
N14	226.091	102.77	-2.7	B-C4	121.217	100.18	-8.4
N2	230.685	104.86	0	B-C5	121.55	100.45	-9.2
N3	225.035	102.29	-1.7	B-C6	120.713	99.76	-5.6
N4	205.958	93.62	-5.8	B-C7	120.047	99.21	-9.4
N5	213.28	96.95	-3.8	B-C8	120.583	99.66	-4.6
N6	209.693	95.32	-4.8	B-GAMA1	11	100	6.6
N7	222.86	101.3	-0.9	B-GAMA2	10.767	97.88	4
N8	210.79	95.81	-4.7	B-RO1	24	100	0
N9	210.054	95.48	-5.1	B-RO2	15.75	100	2.2

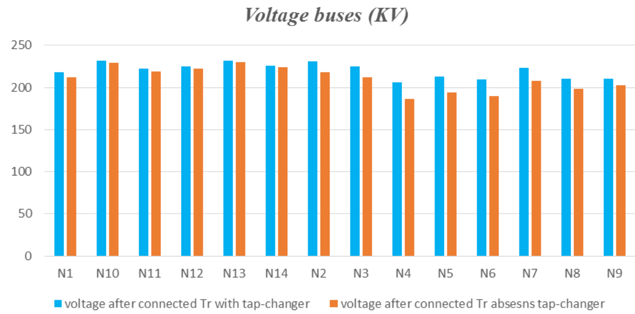


Chart 6. Results voltage buses 220 kV with & without the effect of Tap Changer.

Table 5. Results of power flow of transmission lines after connecting transformers with present Tap changer.

Name	type	P MW	Q MVAr	I KA	Angle °	Loading %	P loss MW	Q loss MVAr
L9	Line	35.429	42.056	0.146	-53.9	18.12	0.4003	-6.9498
L15-2	Line	-116.519	-104.541	0.415	134.1	47.45	1.0781	-32.9358
L10 -1	Line	106.759	58.606	0.303	-26.8	34.67	2.9604	-0.8926
L10-2	Line	132.355	47.443	0.35	-17.7	40.02	2.0095	0.813
L11	Line	52.243	38.942	0.169	-39.2	19.37	0.7939	-10.6775
L15-1	Line	117.597	71.605	0.353	-33.5	40.33	1.0781	-32.9358
L13	Line	17.247	26.725	0.082	-59.3	9.32	0.0876	-7.1123
L14	Line	-42.351	-42.739	0.154	132.6	17.62	0.342	-9.9357
L12	Line	56.006	56.372	0.198	-46	22.61	0.6924	-7.2177
L16	Line	-65.21	-39.53	0.195	146.1	22.25	0.4901	-7.2105
L1	Line	64.655	29.863	0.178	-24.8	20.37	1.0894	-14.2574
L2	Line	-60.197	-39.269	0.184	145.1	21.07	0.4362	-7.4422
L4	Line	-70.368	-53.16	0.247	137.1	28.25	0.6991	-3.1107
L3	Line	-120.171	-94.251	0.428	136.1	48.93	3.8597	8.7041
L5-1	Line	-83.458	-70.106	0.3	135.1	34.3	0.3882	-21.8742
L5-2	Line	-83.458	-70.106	0.3	135.1	34.3	0.3882	-21.8742
L6	Line	-93.89	-58.819	0.305	143.1	37.89	1.7657	-1.3139
L7	Line	143.348	87.557	0.435	-32.3	49.73	2.3322	6.2525
L8	Line	10.574	-1.831	0.029	5.1	3.36	0.0145	-9.7413

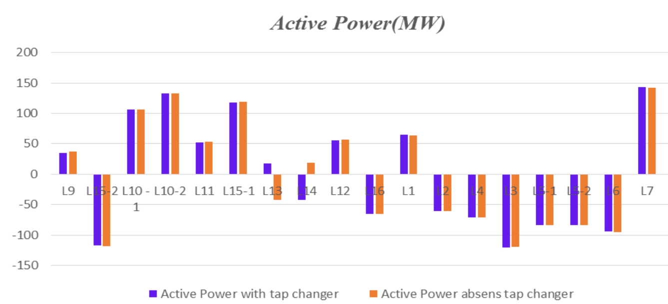


Chart 7. Results of active power flow of lines with & without the effect of Tap changer.

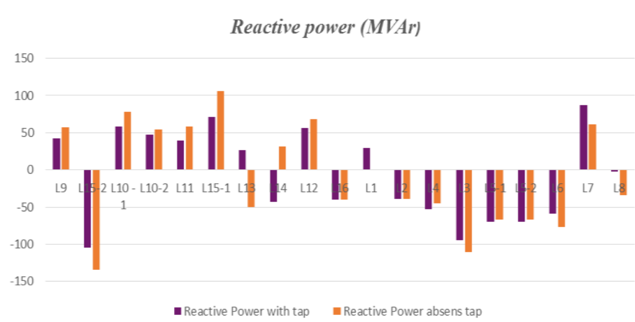


Chart 8. Results of reactive power flow of lines with & without the effect of Tap changer.

Load Flow converged after 18 iterations.

- Network MW Losses = 30.867697
- Network MVAR Losses = 124.95371

6.4. Part I Case study (4): Double Transmission Lines

We will decrease the impedance of the system by supporting weak transmission lines (3,4,6,7) at zone (2) in the previous case by converting it into a double circuit Figure (5). The decreased impedance of the network leads to reduced drop voltage between buses note table (6) which leads to an improving level of voltage, active and reactive power in the TL, also note table (7) & charts (9,10 &11) relative to.

$$Z_{Tot} = Z_{BUSi} + \frac{Zlin}{2} + Z_{BUSk} + Z_{Tr} \quad (5)$$

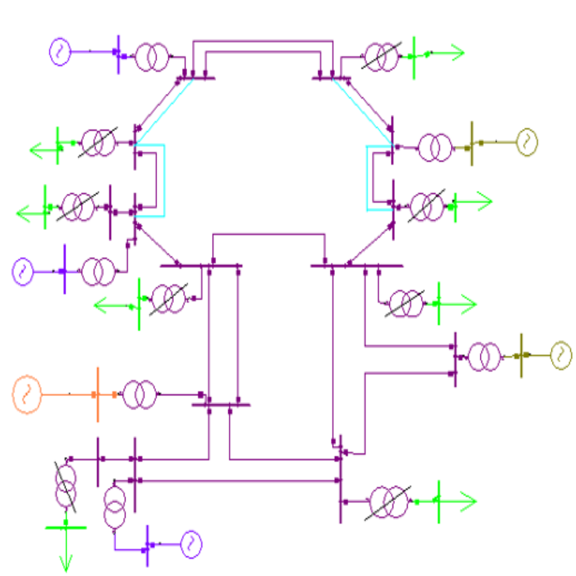


Figure 5. Electrical network variant 2 with support TL.

Table 6. Results voltage of buses after modifying transmission lines.

Name	U KV	U %	U angle °	Name	U KV	U %	U angle °
B-ALFA	15.75	100	2.5	N1	219.985	99.99	-4
B-BETA	15.652	99.38	1.1	N10	233.168	105.99	2.1
B-C1	118.876	98.24	-4.2	N11	223.836	101.74	-2.3
B-C2	121.286	100.24	-6.3	N12	226.566	102.98	-2.1
B-C3	121.011	100.01	-7.6	N13	232.693	105.77	-0.7
B-C4	120.491	99.58	-7.9	N14	226.95	103.16	-2.5
B-C5	120.184	99.33	-9	N2	234.304	106.5	-0.7
B-C6	121.801	100.66	-5.4	N3	228.775	103.99	-2.4
B-C7	121.527	100.44	-9.2	N4	225.033	102.29	-3.6
B-C8	121.061	100.05	-4.4	N5	228.552	103.89	-3
B-GAMA1	11	100	6.8	N6	224.975	102.26	-3.9
B-GAMA2	11	100	2.4	N7	229.184	104.17	-2.3
B-RO1	24	100	0	N8	221.61	100.73	-4.1
B-RO2	15.75	100	2.3	N9	215.02	97.74	-4.8

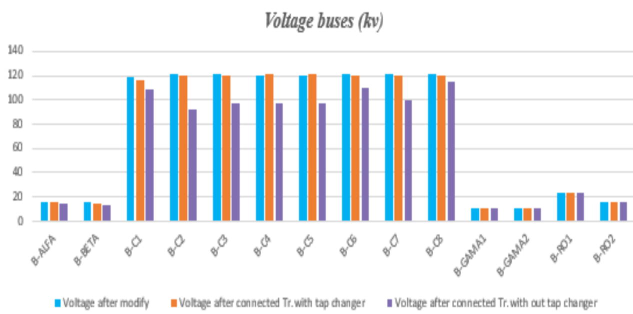


Chart 9. Results voltage of buses 110 and generators before & after modifying.

Table 7. Results of power flow of transmission lines after modification.

Name	type	P MW	Q MVAr	I KA	Angle °	Loading %	P loss MW	Q loss MVAr
L9	Line	26.684	25.284	0.096	-47.4	11.98	0.1844	-8.5013
L15-2	Line	-116.261	-91.978	0.389	137.7	44.47	0.9492	-34.4062
L10 -1	Line	105.335	45.76	0.284	-21.3	32.5	2.5815	-3.8793
L10-2	Line	133.808	44.261	0.349	-16.2	39.88	1.992	0.5439
L11	Line	48.504	25.381	0.141	-29.9	16.14	0.5503	-12.6617
L15-1	Line	117.21	57.572	0.333	-28.2	38.03	0.9492	-34.4062
L13	Line	13.263	21.799	0.065	-60.8	7.43	0.0588	-7.3975
L14	Line	-43.741	-39.692	0.151	135.7	17.2	0.3273	-10.1362
L12	Line	54.653	49.466	0.183	-42.8	20.9	0.5936	-7.9538
L16	Line	-65.21	-39.52	0.194	146.3	22.17	0.4861	-7.3107
L1	Line	56.302	36.132	0.165	-33.4	18.84	0.9794	-15.4896
L2	Line	-60.199	-39.229	0.181	144.6	20.72	0.4209	-7.8663
L3-d	Line	-65.431	-41.781	0.199	143.8	22.76	0.7936	-11.5637
L4	Line	-29.838	-31.865	0.112	129.5	12.8	0.1307	-7.7997
L3	Line	-65.431	-41.781	0.199	143.8	22.76	0.7936	-11.5637
L4-d	Line	29.968	24.065	0.097	-41.7	11.1	0.1307	-7.7997
L6-d	Line	-41.362	-23.336	0.122	146.7	15.14	0.2636	-11.0291
L5-1	Line	-89.04	-76.08	0.301	135.6	34.35	0.385	-25.5365
L5-2	Line	-89.04	-76.08	0.301	135.6	34.35	0.385	-25.5365
L6	Line	-41.362	-23.336	0.122	146.7	15.14	0.2636	-11.0291
L7-d	Line	77.898	55.565	0.241	-37.8	27.55	0.7358	-4.0349
L7	Line	77.898	55.565	0.241	-37.8	27.55	0.7358	-4.0349
L8	Line	23.88	35.947	0.112	-60.5	12.85	0.2465	-9.081

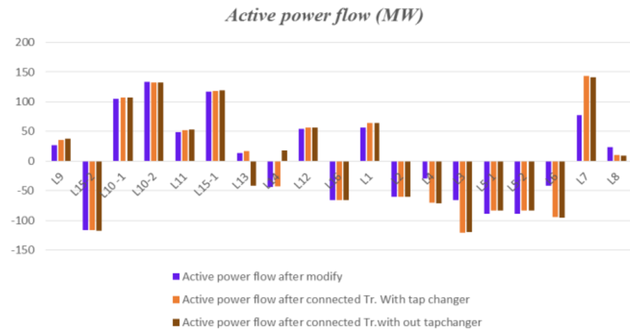


Chart 10. Results of active power flow in lines before & after modifying the system.

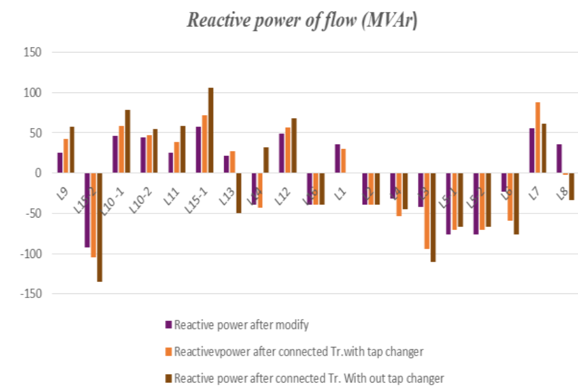


Chart 11. Results of reactive power flow in lines before & after modifying the system.

Network MW Losses = 24.685811.
Network MVAR Losses = 13.088821.

6.5. Part II Case study (1): study the effect of FACT'S and capacitor bank on the Electrical network with pump station

In the first part, the change of network impedance, in general, was simulated by the change of network throughput and its impact on the levels of power flow, in this part the connection of water pumping stations in southern Iraq to a capacity of 75 MVA within the network studied with the levels of power flow in the first part will be simulated where the effect of linking these stations on the levels of power flow, the effect of harmonics, and the current of a fault will be studied. Figure (6). A New case from a scenario of power flow represented by adding a pump station has a total capacity of 24 MW including 12 synchronous Machin as pump motors into our system with the case of hasn't tap changer from this case we note table (8) there is a collapse voltage in buses of the pump station, with rated voltages of 6.6 kV, also have several systems of voltage to feed excitation control for more flexible operating the machine. With optimal parameters of power flow. By operating the tap changer, we have improved the voltage shown in table (9).

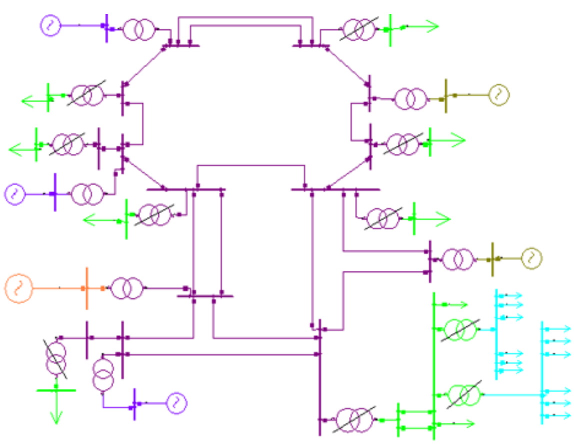


Figure 6. Single line diagram of the electrical network with 12 synchronizations Machin with Tap changer.

Network MW Losses = 31.792407
Network MVAR Losses = 97.821662

Table 8. Results of the voltage of buses which feed to pump after connecting transformers without Tap changer.

Name	U KV	U %	U angle °
B-C6	115.774	95.68	-2.4
B-pump1	5.697	86.32	-9.5
B-pump2	5.697	86.32	-9.5
B-Station	107.406	88.76	-7.5
N10	233.393	106.09	3.6
N11	225.856	102.66	-0.6
N12	226.515	102.96	-1.4
N13	233.22	106.01	0.5

Table 9. Results voltage of buses which feed to pump with operate Tap changer.

Name	U KV	U %	U angle °
B-C6	121.423	100.35	-2.3
B-pump1	6.615	100.23	-8.4
B-pump2	6.615	100.23	-8.4
B-Station	113.614	93.9	-6.8
N10	233.443	106.11	3.6
N11	225.976	102.72	-0.6
N12	226.557	102.98	-1.4
N13	233.263	106.03	0.5

Load Flow converged after 11 iterations.
Network MW Losses = 31.876395
Network MVAR Losses = 100.346216

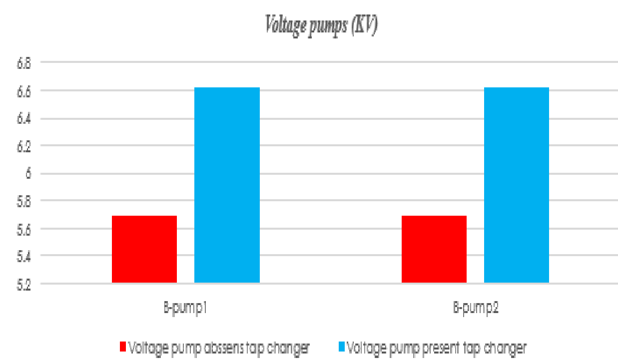


Chart 12. Results voltage buses 6.6 KV synchronous Machine with &without Tap changer.

One of the problems facing the operation of pumping stations is low voltage in the substations of the national network resulting from the failure of the voltage regulator of the power transformer as the chart (12) or a source of generation, resulting from there is a gap between load and generation approximately equal to 35 % which negatively affects the voltage levels, exactly in peak load time and decrease the value of voltage operation to less than 6000v, while the limits areas of operation of the excitation control system in pump station within ±5% from the rated voltage which opposite to ± 330 v that mean failure operation of pumps in many times, this study including some solution to improve level voltage and operate with optimal reactive power flow according to the network conditions. First, from this solution we use a capacitor bank, figure (7). adding a capacitor direct on the busbar which fed the pump station. to reduce reactive power losses by injection capacitor current with lead power factor reverse reactive current which leads to reduced total losses in our network and improves the level of voltage note table (10) and chart (13). Capacitors have the below equation:

$$I_c = \frac{V_c}{X_c} \quad ; \quad X_c = \frac{1}{2\pi f c}$$
$$Q_c = I_c * V_c \qquad (6)$$
$$Q_t = Q_c - Q_l$$

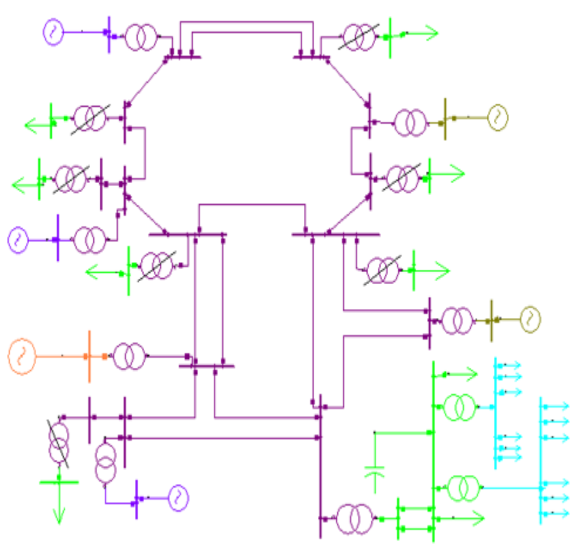


Figure 7. Single line diagram of the electrical network with 12 synchronizations Machin with Tap changer & adding a capacitor.

Table 10. Results of the voltage of buses which feed to pump buses after connecting capacitor.

Name	U KV	U %	U angle °
B-C6	117.873	97.42	-12.7
B-pump1	6.388	96.79	-33.6
B-pump2	6.388	96.79	-33.6
B-Station	119.76	98.98	-32
N10	233.491	106.13	-1.3
N11	225.914	102.69	-6.1
N12	226.945	103.16	-3.6
N13	233.321	106.05	-3.3

Load Flow converged after 12 iterations.
Table 10 and chart 13
Network MW Losses = 47.990014
Network MVAR Losses = 237.351352

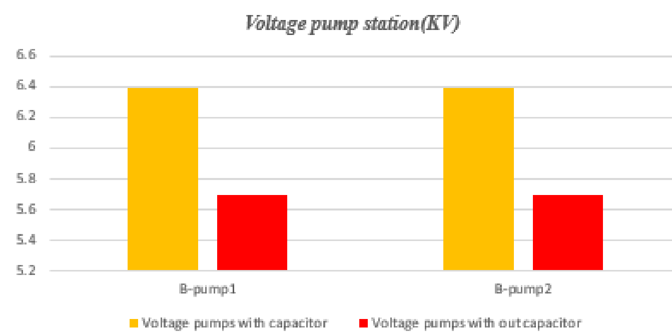


Chart 13. Results voltage buses 6.6 kV with &without effect capacitor.

Or by using SVC Static Var Compensator (SVC) is a power quality device as the second solution with problems of power flow instead to the capacitor bank, Figure (8). which employs power electronics to control the reactive power flow of the system where it is connected. It can provide fast-acting reactive power compensation on electrical systems and improve voltage levels at buses of pump stations as shown in Table (11) and chart (14).

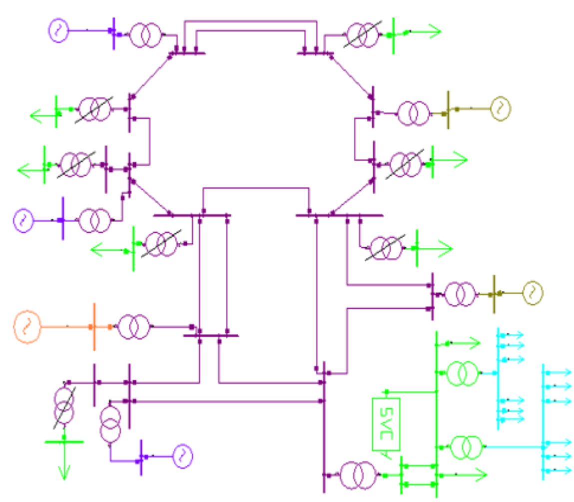


Figure 8. Single line diagram of the electrical network with 12 synchronizations Machin without Tap changer and adding svc.

Table 11. Results of the voltage of buses that feed to pump buses after connecting SVC.

Name	U KV	U %	U angle °
B-C6	121.818	100.68	-2.4
B-pump1	6.626	100.4	-8.9
B-pump2	6.626	100.4	-8.9
B-Station	124.025	102.5	-7.4
N10	235.247	106.93	3.5
N11	230.368	104.71	-0.8
N12	228.03	103.65	-1.4
N13	234.824	106.74	0.5

Network MW Losses = 30.672734
Network MVAR Losses = 79.548672

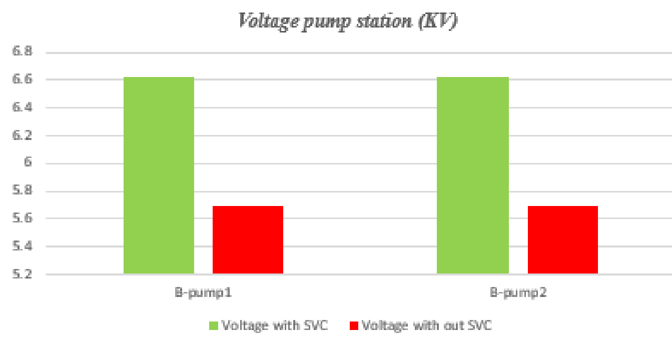


Chart 14. Results voltage buses 6.6 kV with & without effect SVC.

Operation of treatment voltage level as other simulation with adding UPFC instead to the SVC and run Neplan analysis.

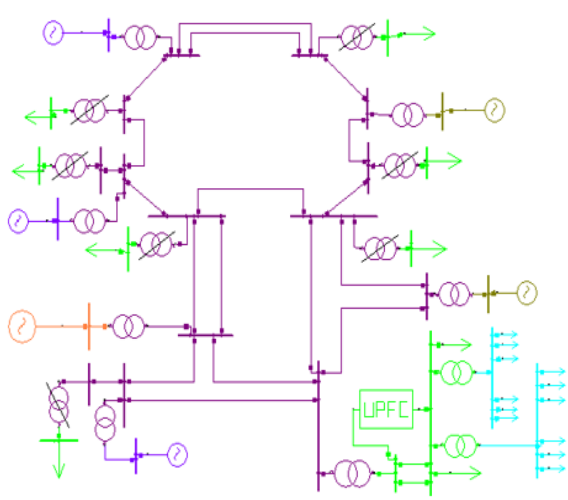


Figure 9. Single line diagram of the electrical network with 12 synchronizations Machin without Tap changer and adding UPFC.

The UPFC is a device that can control simultaneously all three parameters of line power flow (line impedance, voltage, and phase angle).

$$P = \frac{V_i.\ V_k \sin\delta}{(X)} \ and \ Q = \frac{V_i.\ (V_i - V_k \cos\delta)}{(X)} \quad [5]$$

UPFC devices by equations of power can increase the operating range of the transmission system greatly. Especially when δ = 90°, the transmission system has reached the limit point of stable operation, also increasing the level of voltage. Figure (9).

Load Flow converged after 19 iterations.
Network MW losses = 30.720203
Network Mvar losses = 25.627707

Table 12. Results of the voltage of buses which feed to pump buses after connecting UPFC.

Name	U KV	U %	U angle °
B-C6	121	100	-2.4
B-pump1	6.6	100	0.3
B-pump2	6.6	100	0.3
B-Station	123.557	102.11	1.8
N10	234.942	106.79	3.5
N11	229.702	104.41	-0.7
N12	227.77	103.53	-1.4
N13	234.578	106.63	0.5

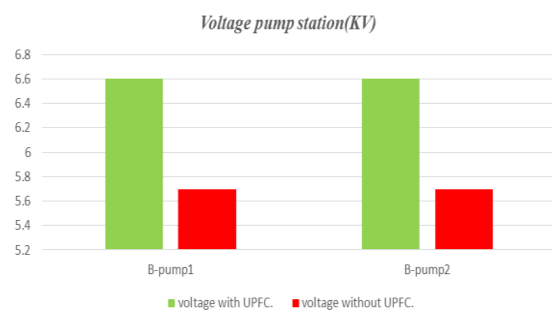


Chart 15. Results voltage buses 6.6 kV with &without effect UPFC.

Where both SVC and UPFC systems were used in our research to obtain a better performance of the characteristics of power flow, and the practical results proved to obtain a better performance with the presence of these systems, with a preference for the work of the UPFC system in the electrical circuit that is the subject of our research. Table (12) and chart (15).

6.6. Part II Case Study (2): Effect of Harmonic Analysis

Harmonics are distortions in the form of voltage and current caused by nonlinear loads in the network. In general, there is a problem encountered in circuits with power electronics elements, as well as other electrical loads with non-linear characteristics that cause harmonic distortions**.** According to IEEE std 519–2014, if there is>8% total harmonic distortion (THD) at the point of common connection (PCC) in a low-voltage system, the system is required to be analyzed in terms of harmonics [12]. This can be given for both current and voltage. Total harmonic distortion for voltage can be expressed as,

$$THDV = \frac{1}{U1}\sum_{n=2}^{\infty} U_n^2 \qquad (7)$$

Total harmonic distortion for current can be expressed as:

$$THDI = \frac{1}{I1}\left(\sum_{n=2}^{\infty} U_n^2\right) \qquad (8)$$

Harmonics are popular power quality distortion of recent years that is being spoken about more and more every day and has different distorting impacts in many different facilities. In this case, we can note problems with the appearance of harmonics in pumps (1,2,4,7) shown in figure (11) due to the presence of soft start systems electronic devices, which leads to the pollution of voltages and transfer harmonics to all buses of the electrical system as shown in the table (13).To solve the problem we are using 4 passive filters that connect each two with the busbar of the pumps as in Figure (10), we note the pollution of harmonic will be decreased, table (14) & chart (16) compare the value of THD before and after connect filters.

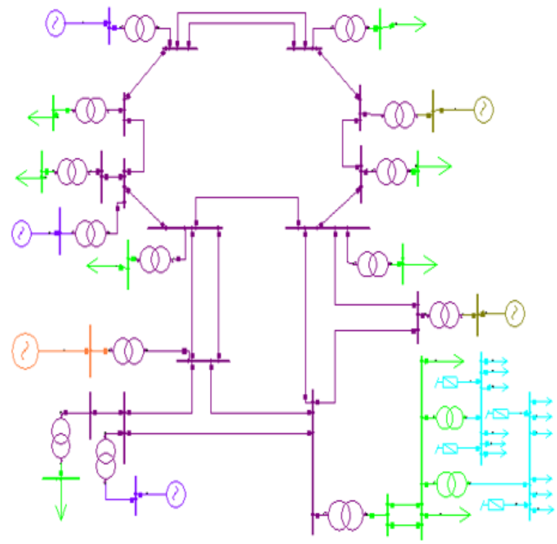


Figure 10. Single line diagram of the electrical network with 12 synchronizations Machin with Harmonic Analysis after adding filters

Table 13. Parameters of Harmonic in all buses.

Name	THD %	f HZ	U V	u %	U ang °
B-pump1	1.56	150	102.438	1.55	194.83
B-pump2	2.07	150	74.655	1.13	233.5
B-Station	1.1	150	897.088	0.79	208.87
N1	0.64	150	217.946	0.1	203.09
N10	0.47	150	241.196	0.1	205.94
N11	0.62	150	381.716	0.17	206.17
N12	0.58	150	228.447	0.1	204.64
N13	0.51	150	246.153	0.11	205.23
N14	0.52	150	237.947	0.1	203.51
N2	0.33	150	80.936	0.03	201.29
N3	0.34	150	78.597	0.03	199.81
N4	0.35	150	58.652	0.03	196.59
N5	0.33	150	51.973	0.02	196.29
N6	0.35	150	55.38	0.03	196.05
N7	0.32	150	85.8	0.04	199.94
N8	0.46	150	143.688	0.07	200.31
N9	0.62	150	231.176	0.11	202.75

6.6.1. Calculation of filter:

1- Calculate the size of QC (MVAr) needed to oppose the reactive power of the harmonic source [13].
2- Calculate the capacitor's reactance.

$$X_c = \frac{kv^2}{Q_c} \qquad (9)$$

3- Determine the value of inductive reactance by the equation:

$$XL = \frac{X_c}{h_n^2}$$

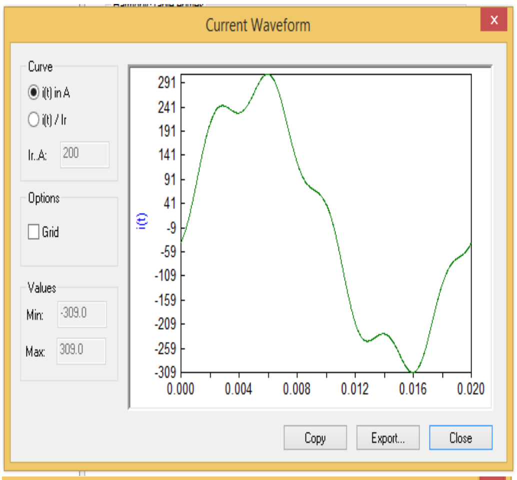
$$XL = 2\pi f l \qquad (10)$$

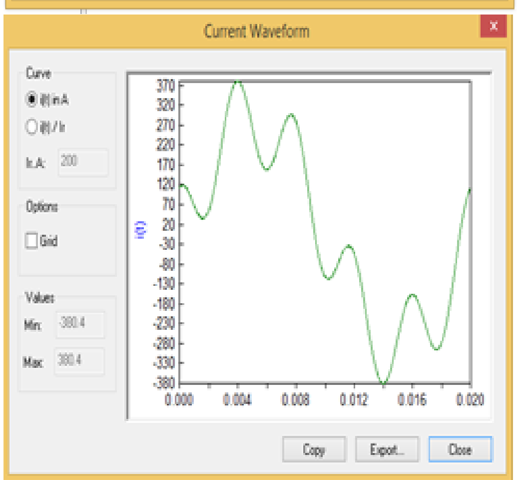
4- calculate the characteristic reactance X_n and the resistance of reactor R

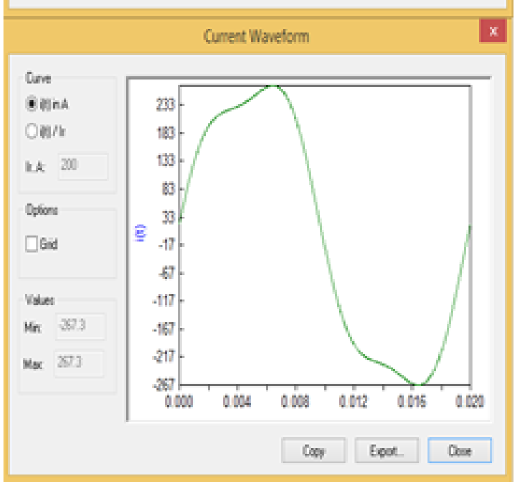
$$X_n = \sqrt{XL\ X_c};\ \mathrm{R}=\frac{X_n}{Q} \quad (11)$$

5- find the size MVAr of the filter

$$Q_{filter} = \frac{kv^2}{X_c - XL} \quad (12)$$







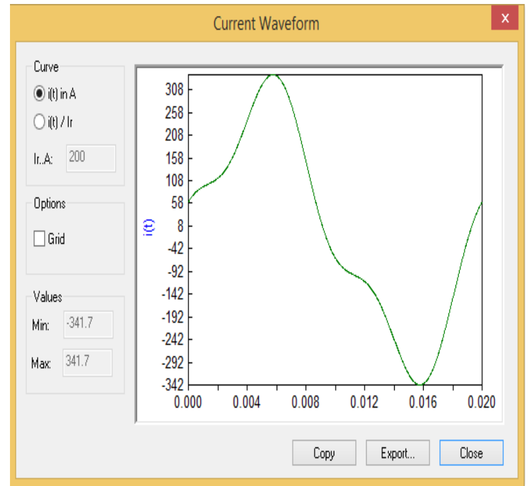


Figure 11. The curve of harmonic at pumps.

Table 14. parameters of harmonic in all buses after adding filter.

Name	THD %	f HZ	U V	u %	U ang °
B-pump1	1.16	150	75.913	1.15	184.44
B-pump2	1.47	150	50.393	0.77	230.55
B-Station	0.84	150	625.269	0.63	200.43
N1	0.41	150	151.908	0.07	194.66
N10	0.3	150	168.113	0.07	197.5
N11	0.41	150	266.056	0.12	197.74
N12	0.37	150	159.227	0.07	196.2
N13	0.32	150	171.568	0.07	196.79
N14	0.33	150	165.848	0.07	195.08
N2	0.21	150	56.412	0.02	192.85
N3	0.22	150	54.782	0.02	191.37
N4	0.23	150	40.88	0.02	188.15
N5	0.22	150	36.225	0.02	187.85
N6	0.23	150	38.6	0.02	187.61
N7	0.21	150	59.802	0.03	191.5
N8	0.3	150	100.15	0.05	191.88
N9	0.4	150	161.129	0.08	194.31

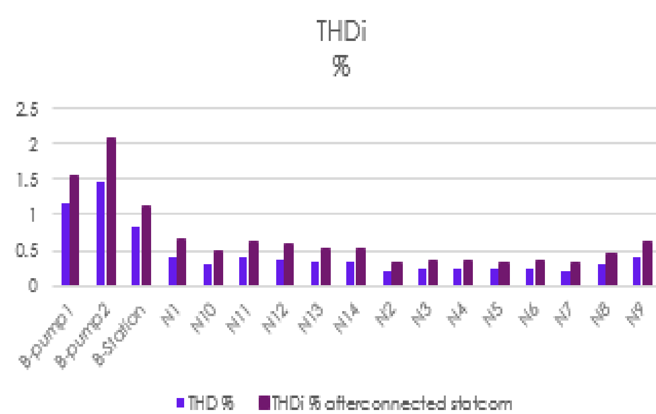


Chart 16. Results of THDi % before and after adding filter at buses of pumps station.

6.7. Part II Case study (3): Effect of Short Circuit Current

The symmetrical fault which the most severe fault is occurs in a power system by simulating the fault on the busbar of pump no (1) and using Neplan software analysis we are getting following the result as in Chart (17), Table (15).

- When the fault occurs, the AC component of the current jumps to a very large value.
- All buses' transient current I_k'' did not exceed the required value of the short circuit level of the circuit breaker and other devices (40kA) in the network.
- Sub transient current ip initial peak value within a level of a factor between transient current and sub transient current is approximately 2.5 where $ip = k_b\sqrt{2}\, I_k''$ [8].
- Before the fault, only AC component voltages and currents are present, but immediately after the fault, both AC and DC components are present, The DC component makes the symmetrical current asymmetrical. The value of the DC component in the simulated result is very small. And depending on a time constant $\frac{X}{R}$ Where it affects the peak short circuit current

  $$ip = 1.15\, k_b\sqrt{2} I_k''$$

  $$k_b = 1.02 + 0.98\, e^{-3R/X} \qquad [7]$$

- All buses far from the generator have an initial symmetric short circuit equal to a short circuit breaking current.
- For short circuits a near from generating the initial symmetric short circuit greater than breaking current by factor **μ** with delay time =0.10s.
- As observed from the result of post-fault voltages during the fault, the increased value of the voltage at faulted buses to value equal to the voltage multiplied by the voltage factor is equal to 245 kV within the level of maximum Rated voltage, also there is a voltage drop voltage is in the neighboring buses, show tables.

6.8. Part II Case study (3) Fault current with CLR

Adding impedance to impedance of fault as current limiting reactor (CLR) explain above in part "Analysis of short circuit current" and connecting as series impedance with a load Figure (12). lead to an increase in the total impedance of the short circuit and reduces the value of short circuit current depending on the following relationships:

$$Z_{SC} = \sqrt{Z_S + X_R}; \quad I_{Fault} = \frac{V}{Z_{SC}}$$

$$X_R = \frac{V}{\sqrt{3}}\left[\frac{1}{Isc\,before} - \frac{1}{Isc\,after}\right] \qquad (13)$$

And note the effect of CLR on the current fault in Chart (17), Table (15), as below.

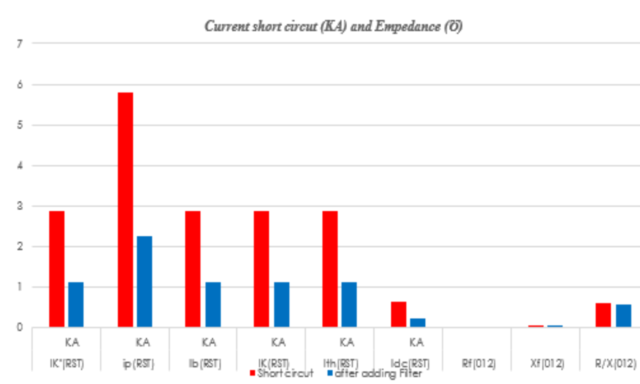


Chart 17. Results Short Circuit current and impedance after & before adding Filter.

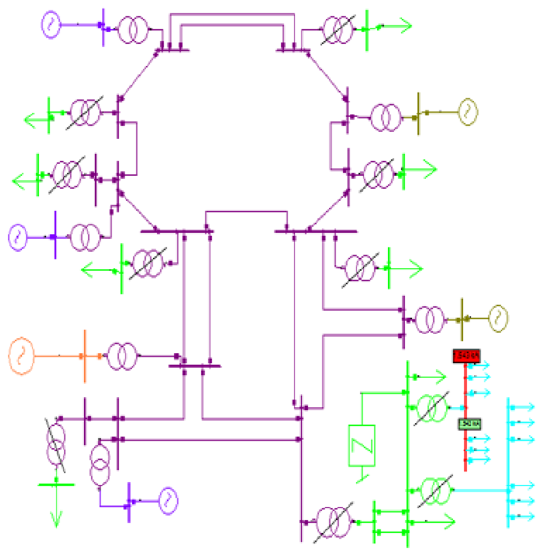


Figure 12. Single line diagram of the electrical network with synchronization Machin with Short Circuit after adding *(*CLR*)*.

Table 15. Results Short Circuit current and impedance before & after adding Filter.

IK"(RST) KA	ip(RST) KA	Ib(RST) KA	IK(RST) KA	Ith(RST) KA	Idc(RST) KA	Rf(012)	Xf(012)	R/X(012)
2.877	5.796	2.877	2.877	2.879	0.637	0.0374	0.0609	0.614
1.12	2.253	1.12	1.12	1.121	0.245	0.0354	0.0605	0.586

7. Conclusion and Scientific benefit

The network impedance calculation is necessary to determine the power flow vocabulary. And The relationship between network impedance and voltage levels and effective power is an inverse relationship. Using fax systems that are more effective than the classic systems to compensate for ineffective capacity losses. When Connecting SVC systems at pumping stations to maintain the induction voltage level when the pumps start running. The emergence of harmonics in the network is linked to the presence of electronic sources used in water pumps, represented by the soft star. The use of series-connected impedance in the path of the fault current is more effective than the use of FACT'S systems to reduce the effect of the fault current. The operation of the voltage regulator in national grid power transformers is essential to improve voltage levels and reduce reactive power losses. Maintaining the continuity and permanence of pump work without interruption and overcoming the problems of interruption of the induction voltage of the pumps. The fact that the stations represent the only source of drainage in Iraq, with a total capacity of 400 MVA throughout Iraq, and a water drainage capacity of 10 million cubic meters per second, and the continuation of their work is considered a practical necessity.

Conflict of interest

We, the authors, acknowledge and confirm that all scientific information has been obtained from the use of practical experiments and their simulations in reality without plagiarism from any other articles and research. The authors confirm that there is no conflict of interest.

Author Contribution Statement

All authors contributed to writing and editing this manuscript. The research problem was proposed by the author, Juman Hadi, and the results of this work were supervised by Dr. Fatih Korkmaz The authors, Dr. Fatih Korkmaz and Juman Hadi, developed the introduction and style of the manuscript. All authors discussed the results and contributed to the final manuscript.

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