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Operation Enhancement by UPFC for long-term planning of Kurdistan Regional Power System

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Abstract

The Unified Power Flow Controller (UPFC) is an essential device to control power flow along the transmission lines. In this paper, the power system analyses of Kurdistan Region (KR) electric networks are studied with and without UPFC. The numbers of buses for current Kurdistan Region power system are 176 buses, the numbers of loads are 112 connected load and the total numbers of branches are 254 branches. The proposed networks include long-term planning (2025-2026). Power System Simulation for Engineering (PSS/E) software is used in this work from Electrical Ministry of Kurdistan Region. In this term, the studying of power flow analysis is done using Newton-Raphson (NR) method, and it appeared that the voltage at most nodes are below the allowable limits (0.9-1.1) P.U, therefore UPFC placed in the network, which is consider the forceful device in Flexible AC Transmission System (FACTS) members, to improve the voltage profile, control power flow and minimize real and reactive power flow.

1. Introduction

Kurdistan Region is an autonomous region in the northern part of Iraq. The voltage levels of Kurdistan power system are (11, 13.8, 15, 33, 132, and 400) kV for transmitting power. The main substations usually consist of (132/33 kV) two winding transformers and (132/33/11 kV) three winding transformers. There are several (33/11 kV) substations connected to each (132 kV) main substation via (33 kV) network. Medium voltage distribution is at (11 kV), which reduces voltage to (400 V) by step down transformer at distribution transformers.Generation supply of KR is depended on Hydro-Power Stations, Gas Power Stations, Diesel Power Stations and Heavy Fuel Stations [1]. The estimated numbers of customers are yearly increasing, so it is needed to develop and improve the electricity network of Kurdistan Region. The load demand has grown rapidly and becomes double for next ten years in case low growth of population forecasting [2]. Thus, UPFC is proposed and implemented to improve voltage profile, control power flow and minimize power losses. In 2014, M. Ismail, et.al [3] presented a Multi-objective Optimization Evolutionary Algorithms (MOEA) to solve optimal reactive power dispatch problem using TCSC and UPFC on IEEE 30 bus test system. This method aims to determine the optimal voltage and reduce real power losses in lines. The result shows that the UPFC achieves better solution for voltage stability than TCSC in a certain bus. In 2015, Promod K. Pandey and Baidyanath B. [4] described a comparative study of voltage profile improvement of a grid connected distributed generation with the help of UPFC and SVC, the result shows that the UPFC is much better than UPFC. In 2015, Musa M. and Musa A. Sarki [5] presented the achievement of UPFC for control active and reactive power flow on a 500 kV interconnected lines for compensation and control of power transmission capability. The simulation results show that the UPFC has an excellent ability to control real and reactive power flow. In 2016, M. S. Suresh and M.

S. Indira [6] presented a proper location for installing UPFC to control real power flow to overcome the overloading of transmission line, enhance voltage magnitude and to improve the system stability or security under contingencies analysis.

Unified Power Flow Controller

In power system, the power flow between the two terminals depends on voltage magnitude, angles difference between the terminals and the impedances of the lines connecting the two terminals. UPFC has the ability to control all these parameters to improve power system utilities.

The Unified Power Flow Controller concept was proposed by Gyugyi in 1991[7]. UPFC has two part of Voltage Source Converters (VSC). One of them connected in shunt in a line and the other in series which are connected back-to-back through a DC capacitor that let real power to circulate between the converters so each one can independently generate or absorb the reactive power at its own AC output terminal.

The real and reactive power flow equations with and without UPFC is illustrate as below:

- **Without UPFC [8]**

The transmitted real power:

$$P = \frac{V_1 . V_2}{X} . \sin(\delta) \qquad (1)$$

The transmitted reactive power

$$Q = \frac{V_2 (V_1 \cos(\delta) - V_2)}{X} \qquad (2)$$

- **With UPFC [8]**

The transmitted real power:

$$P = \frac{V_1 . V_2 \sin(\delta) + \Delta V \, V_2 \sin(\theta)}{X} \qquad (3)$$

The transmitted reactive power:

$$Q = \frac{V_2 (V_1 \cos(\delta) + \Delta V \cos(\theta) - V_2)}{X} \qquad (4)$$

2. Simulation of KR Network

The implementation of steady state UPFC model in PSS/E as follows:

- The series part is connected between two buses through dummy bus.
- The shunt part is connected between sending end bus and the ground.
- The series part maintains the desired active and reactive power flows (P_{des}&Q_{des}).
- The shunt part maintains the desired sending end voltage magnitude(V_{set}).

In 2025, it is expected to add more operating stations to KR power system, so the system is modeled with additional power generation by PSS/E software for this year. The total generation power becomes 6704 MW, but the voltages of 8 buses become under the allowable limit of (0.9 P.U) in different places in the system. To solve this problem, UPFC is suggested to add to the system with operating points are P_{des} is 100 MW, Q_{des} is 80 MVAR and V_{set} is 1.000 P.U.

After testing, the UPFC insert between 12- AKRE2 (in DUHOK) and 24-HARIR 400 kV in (ERBIL). 12 and 24 are bus bar codes; AKRE2 and HARIR 400 kV are bus bar names. Considering HARIR is sending bus and AKRE2 is receiving bus with dummy bus (30 UPFC).

3. Results

After inserting UPFC between Harir and Akre, UPFC works to set Harir bus bar to 1.0 P.U, also increases the voltage of Akre bus bar as shown in Table 1.

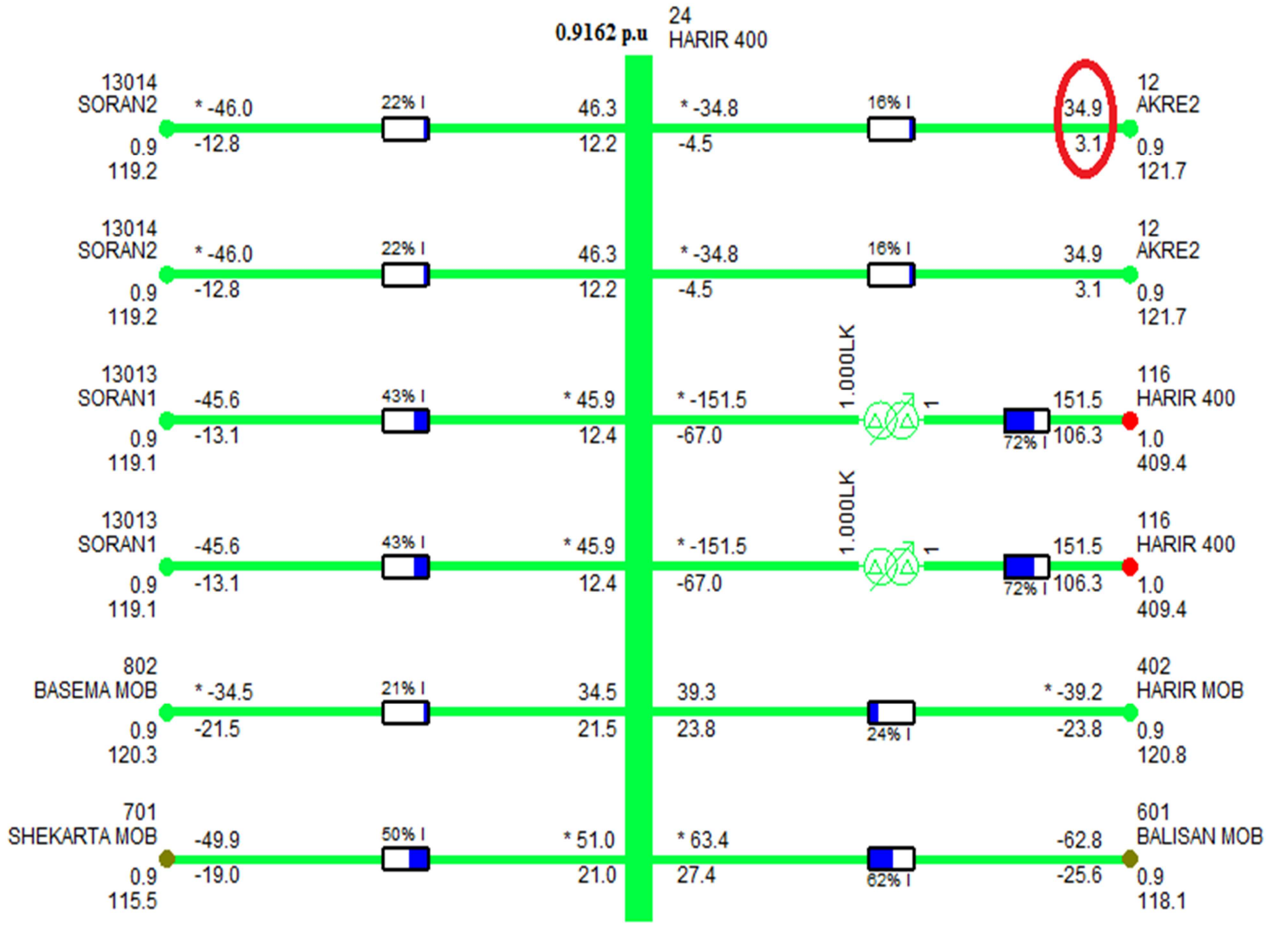
Table 1: Voltage profile of AKRE & HARIR before and after UPFC in 2025

Bus name	Voltage (P.U) without UPFC	Voltage (P.U) with UPFC
12-AKRE2	0.9222	1.0025
24-HARIR	0.9162	1.0000

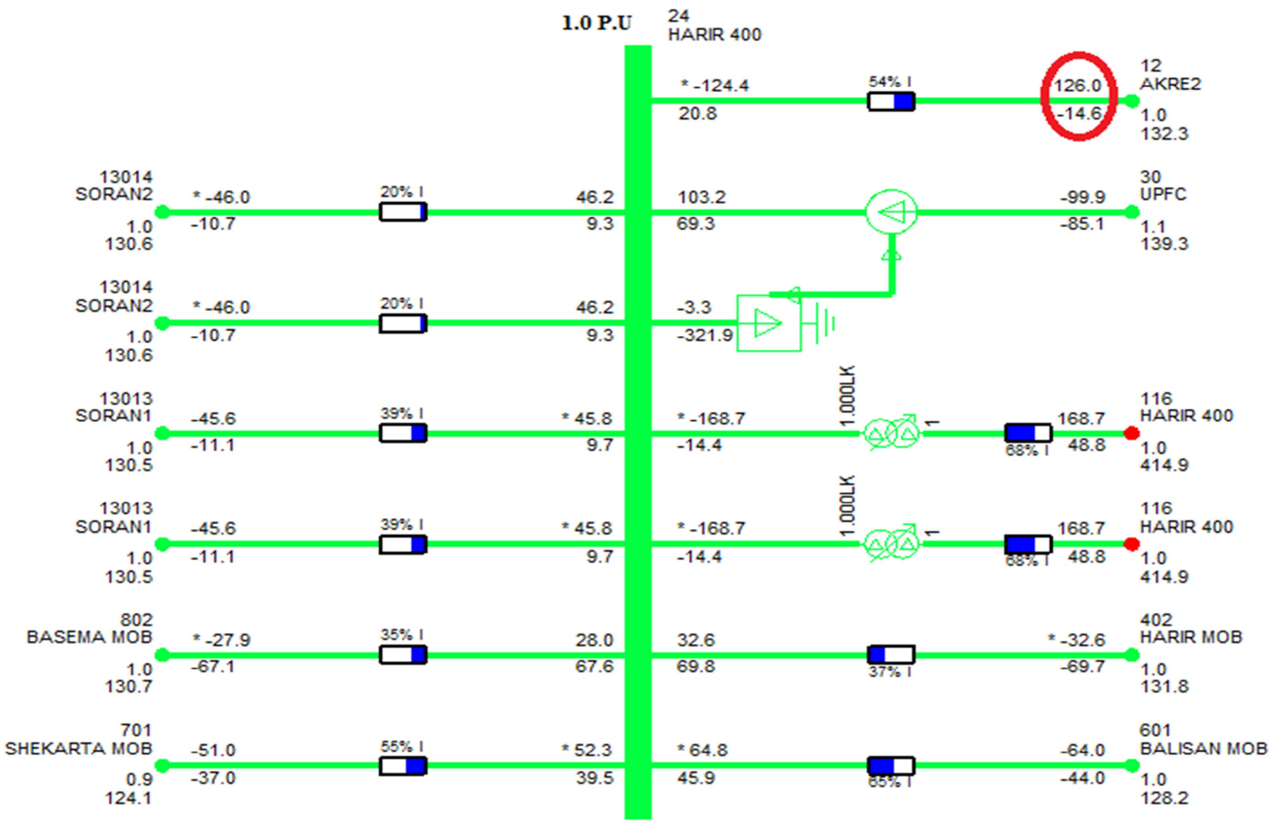
There are double circuits between 24-HARIR 400 kV and 12-Akre2. It is clearly seen from the Figs 1 and 2 that the power of the AKRE2 bus is increased due to the insertion of UPFC powers .The flow in the line between buses AKRE2-HARIR 400 kV has increased from 34.9 MW to 126 MW. And, the second line which connected with series part of UPFC also increased from 34.9 MW to 98.4 MW.

The below is shown the meaning of bus bars color as in Figs 1 and 2

- Normal voltage bus bar
- Under voltage bus bar
- 400 kV bus bar

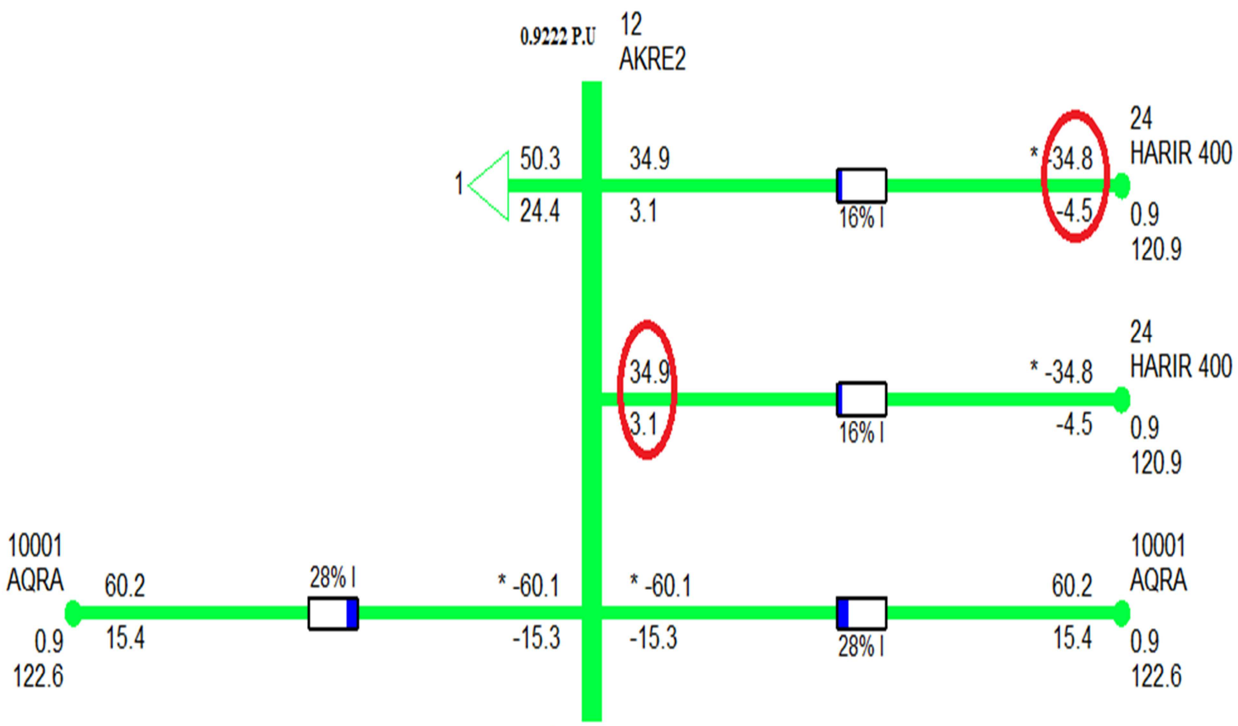


a-HARIR Bus-Bar without UPFC.

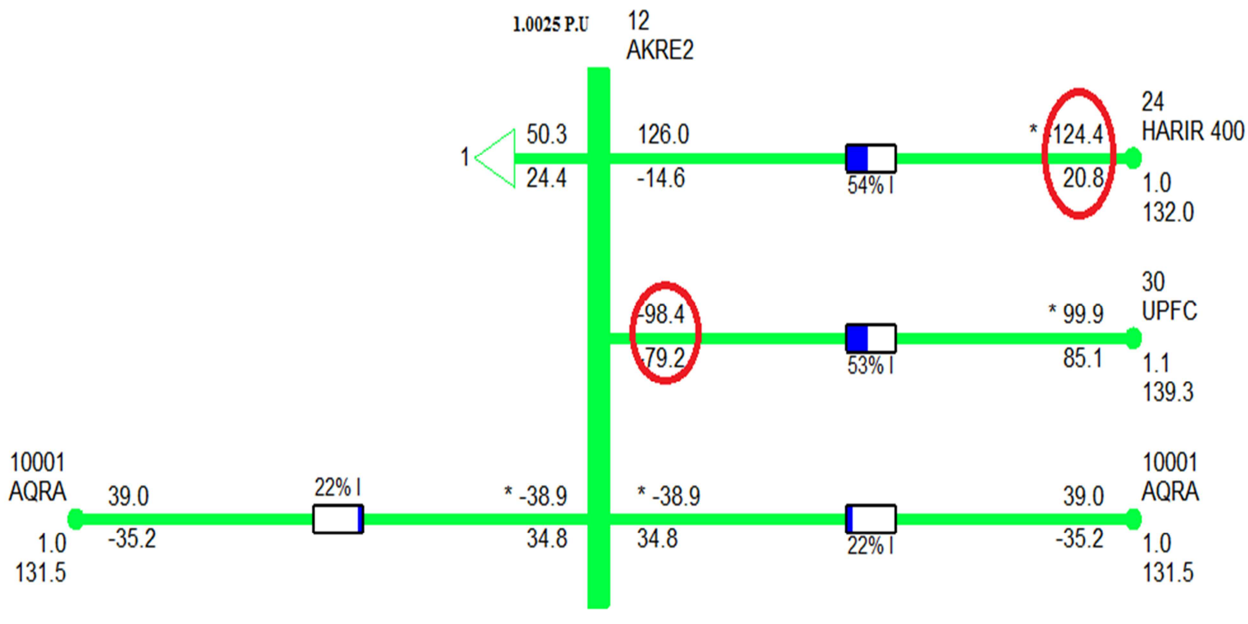


b-HARIR Bus-Bar with UPFC.

Figure 1: The Lines Power Flow for Sending Terminal in 2025.



a-AKREA Bus-Bars without UPFC.



b-AKREA Bus-Bars with UPFC.

Figure 2: The Lines Power Flow for Receiving Terminal in 2025.

The power flows of double circuits between two bus bars are increased. Also, the power flows of other brunches are changed as shown in Table 2.

Table 2: Power flow with and without UPFC in 2025

Branches	Without UPFC		With UPFC	
	MW flow	MVAR flow	MWflow	MVAR flow
24-HARIR to 12-AKRE2	34.9	3.1	126	14.6
24-HARIR to 30-UPFC	34.9	3.1	98.4	79.2
24-HARIR to 802-BASEMA	34.5	21.5	27.9	67.1
24-HARIR to 701- SHEKARTA	49.9	19	51	37
24-HARIR to 13013- SORAN1	45.9	12.4	45.8	9.7
12-AKRE2 to 10001- AQRA	60.2	15.4	39	35.2

Placing UPFC in the system eliminates all the bus voltage violations. The results of voltage profile improvement, when UPFC existing, are given in Table 3 and shown in Fig 3.

Table 3: Voltage profile with and without UPFC in 2025

Bus Name	Area Code	Voltage (P.U) without UPFC	Voltage (P.U) withUPFC
15001-DBSP	2	0.8917	0.9256
701-SHEKARTA MOB	13	0.8749	0.9401
211-REZAN	13	0.8895	0.978
601-BALISAN MOB	13	0.8944	0.9711
13003-SLDN	13	0.899	0.9503
14010-CHRK	14	0.8715	0.9327
303-RANYA	14	0.8699	0.9313
13092-QALADZA	14	0.8637	0.9259

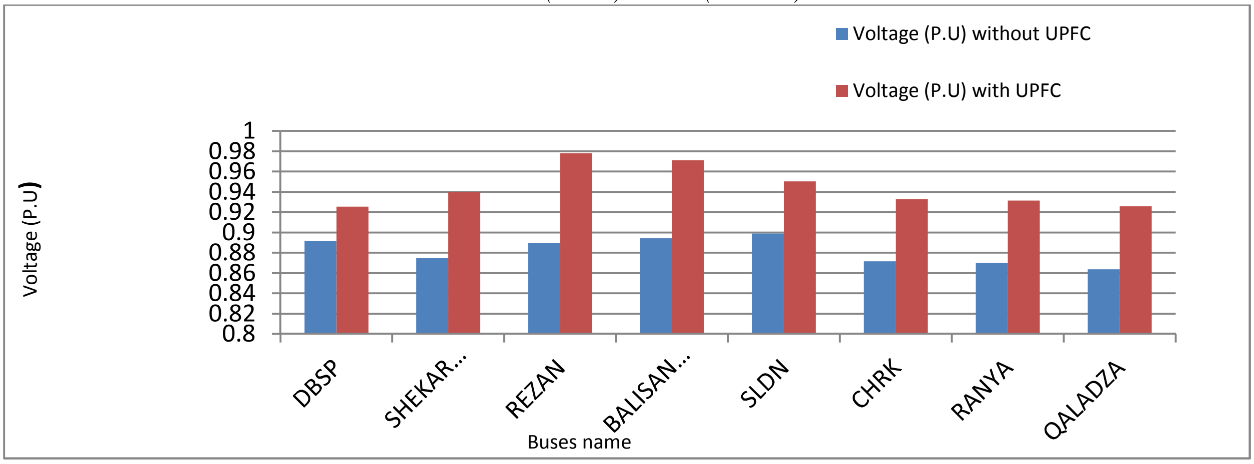


Figure 3: Voltage Profile with and without UPFC in 2025.

UPFC has the ability to minimize the total losses of MW and MVAR in a system. After placing UPFC in KR power system, the real power losses decreases by 3% and reactive power losses decreases by 7.4% as shown in Table 4.

Table 4: Power flow losses with and without UPFC in2025

Power losses	Without UPFC	With UPFC
MW losses	107.4	104.3
MVAR losses	1265.3	1172.1

4. Conclusions

Because of increasing in load demand next ten years, KR power system needs to increase total generations so that installing more 400 kV stations, and operating more additional MW in various stations in KR until the total generation becomes 6704 MW. Therefore the voltage of 8 buses is under 0.9 P.U, but when adding UPFC to the system, all those under voltage buses are improving. And, the flow in the double circuits between buses AKRE2-HARIR 400 kV is increased. In addition, minimize total power losses in KR system.

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