Enhancement of the Performance of Al-Qatraneh 33-kV Transmission Line Using STATCOM: A Case Study

Ali Hamad, Ibrahim Al-Drous, Saleh Al-Jufout

Abstract—This paper presents a case study of using STATCOM to enhance the performance of Al-Qatraneh 33-kV transmission line. The location of the STATCOM was identified by maintaining minimum voltage drops at the 110 load nodes. The transmission line and the 110 load nodes have been modeled by MATLAB/Simulink. The suggested STATCOM and its location will increase the transmission capability of this transmission line and overcome the overload expected in the year 2020. The annual percentage loading rise has been considered as 14.35%. A graphical representation of the line-to-line voltages and the voltage drops at different load nodes is illustrated.

Keywords—FACTS, MATLAB, STATCOM, transmission line, voltage drop.

I. INTRODUCTION

FLEXIBLE Alternating Current Transmission System (FACTS) devices are based on power electronics and designed to enhance the power system performance and increase the capability of power transfer. Using a FACTS device can enhance the transmission capacity of up to 50% [1]. FACTS devices have many advantages: enhancement of transmission capacity, power flow control, improvement of transient stability, damping of power oscillation and voltage control and stability. One of these FACTS devices is the static synchronous compensator (STATCOM). It is a power-electronics voltage-source converter that can act as either a source or sink of reactive power [2]. Supporting power systems that have a low power factor and bad voltage regulation can be achieved by using STATCOM.

A huge amount of research has been conducted on STATCOM. In [3], a genetic algorithm to define the optimal location of FACTS devices is developed. The location of the devices, their types, and their values were used as the parameters of the optimization.

In [4], the optimization of the location, the type and ratings of FACTS devices and the investment cost are considered. Authors in [5] investigated the use of the unified power flow controllers to improve power system dynamics. The impact of FACTS on the voltage stability in power systems and the mathematical models of some FACTS devices are targeted in [6]. Reference [7] defined optimal location for a STATCOM

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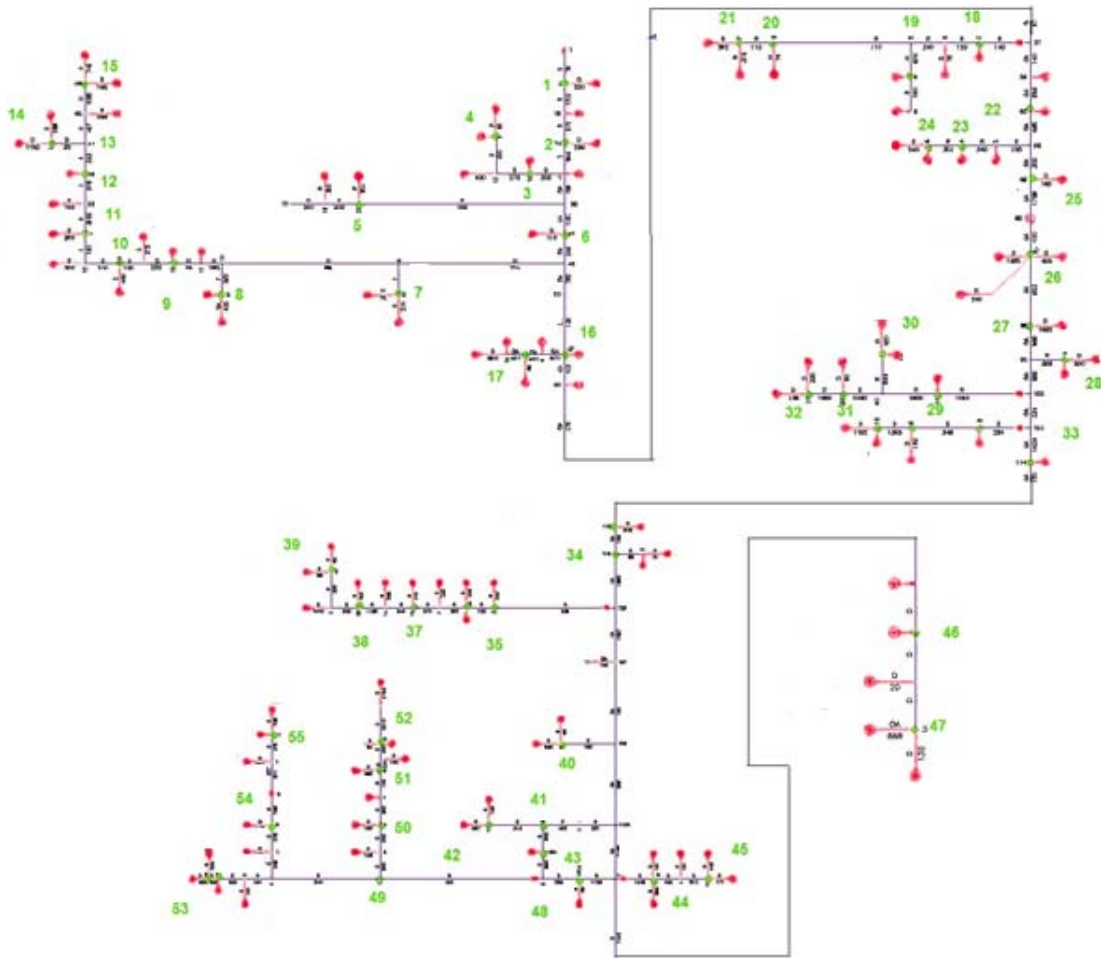
combined with an energy storage system in power systems. This optimization is based on minimum of the transmission line losses and maximum of the transmitted power. Authors in [8] analyzed the use of STATCOM on the Ghanaian power system. They had compared between the use of a fixed compensator and a STATCOM. In [9], the voltage profile of a grid connected wind energy conversion system is improved using a STATCOM. This study was accomplished using MATLAB/Simulink platform. In [10], an ordinal optimization STATCOM installation strategy is suggested to increase the efficiency of solving the mixed discrete–continuous nonlinear optimization problem.

II. THE STUDY TRANSMISSION LINE

In the Jordanian electrical power system, 132 kV and 400 kV transmission networks interconnect the electrical power plants with the load centers at different areas in the country. 230 kV and 400 kV tie lines connect Jordan with Syria and 400 kV tie line connects it with Egypt (Red Sea 400-kV cable).

The total Jordanian system installed capacity is about 3.186 GW. The total installed capacity of the substations is 10.303 GVA [11]. Al-Qatraneh is a Jordanian town, which is located 85 km to the south of the capital city Amman. Al-Qatraneh main electrical substation 132/33 kV provides three main transmission lines: Al-Qatraneh, Al-Sultani and Al-Ljoun transmission lines. This paper will focus only on Al-Qatraneh transmission line shown in Fig. 1.

The length of Al-Qatraneh transmission line is 60 km. It supplies 110 load nodes with distribution transformers 33/0.4 kV ranging from 50 to 1500 kVA. The data obtained from the Electrical Distribution Company (EDCO) was for the year 2013, where the total load is 15.09 MVA. The annual load increase is about 14.35%. After seven years, in 2020, the transmission line is expected to be overloaded. The objective of this work is to increase the loading capability of the study transmission line using STATCOM to handle the expected load in the year 2020.

The system shown in Fig. 1 is modeled by MATLAB/Simulink. In order to decrease the number of computation by two, only 55 nodes are considered for STATCOM installation. Each consecutive two nodes are considered as one node. These nodes are numbered in green in Fig. 1.

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Fig. 1 Single-line diagram of Al-Qatraneh transmission line

As shown in Fig. 1, the study electrical power system consists of Al--Qatraneh main electrical supply substation 132/33 kV, short transmission lines, distribution transformers 33/0.4 kV and 110 load nodes. The main substation is modeled by a three-phase source. Short transmission lines are represented by their series resistive-inductive equivalent circuits. Distribution transformers are represented by the MATLAB/Simulink transformer model. The 110 loads are modeled by resistive-inductive-capacitive load branches (MATLAB/Simulink load model). Finally, the STATCOM MATLAB/Simulink model is used to represent the connection of a STATCOM to the study power system.

III. RESULTS AND DISCUSSIONS

The MATLAB/Simulink model of the study power system is used to calculate the steady-state conditions. Fig. 2 shows the line-to-line voltages at the load nodes in the year 2013, where the line-to-line voltage average is 0.383 kV, and the average voltage drop is 4.25%.
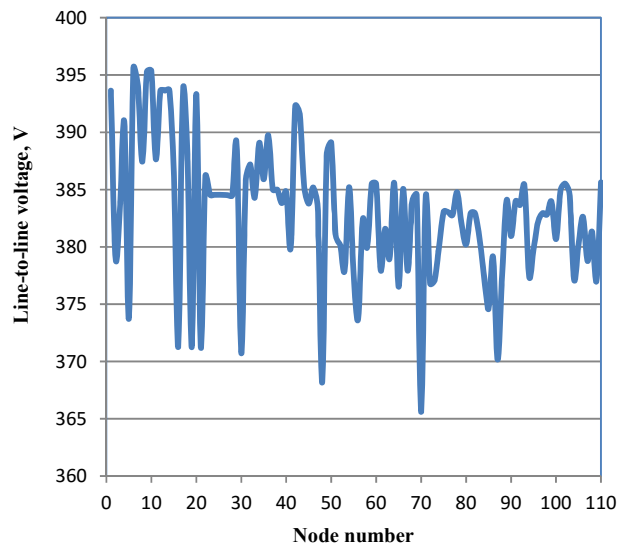
Fig. 2 Line-to-line voltages at load nodes in the year 2013

Fig. 3 shows the line-to-line voltages at the load nodes as

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expected in the year 2020, where the line-to-line voltage average is 0.370 kV, and the average voltage drop is 7.5%. The node loads were increased by 14.35% per year.
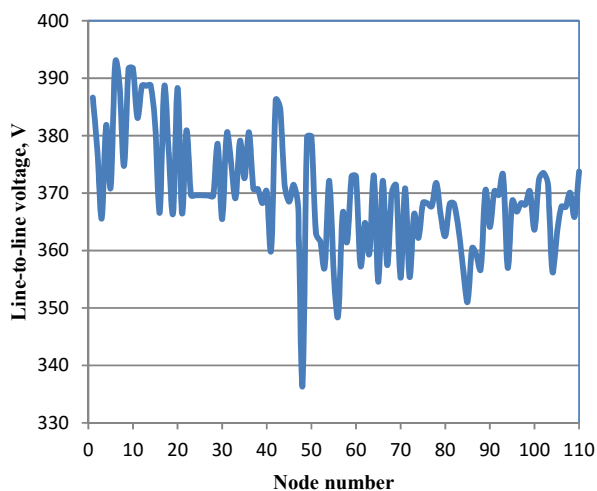

Fig. 3 Line-to-line voltages at the load nodes as expected in the year 2020

To overcome the voltage drop expected in the year 2020, it is suggested to install a STATCOM. This STATCOM was installed at loads with odd numbers (1, 3, …, 109); this is to decrease the computations by half, i.e. the STATCOM was installed at 55 locations.

Fig. 4 shows the average line-to-line voltages at the load nodes as expected in the year 2020 with a STATCOM installed at nodes with odd numbers (55 locations).
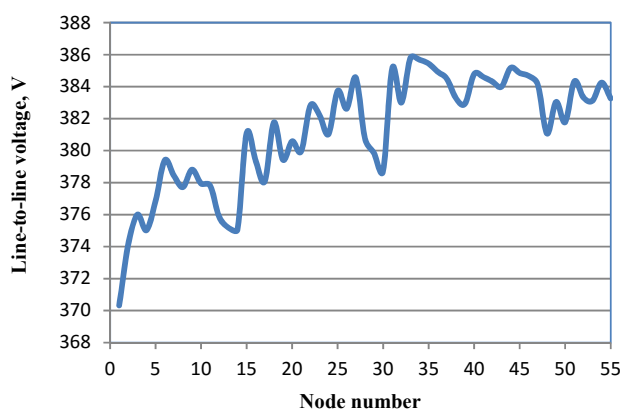

Fig. 4 Average line-to-line voltages of the load nodes as expected in the year 2020 with a STATCOM installed at different nodes

As shown in Fig. 4, the minimum average line-to-line voltage at the load nodes is when the STATCOM is installed at location 1, which is at the sending end of the transmission line while the maximum average line-to-line voltage at the load nodes is when the STATCOM is installed at location 33, which corresponds to load node number 65. To ensure that

load node number 65 is the best location for the STATCOM to be installed, the same calculations were performed with the STATCOM installed at load node number 64 and 66, which were skipped.

Fig. 5 shows a comparison of the line-to-line voltages at the load nodes as expected in the year 2020 without (the red lower curve) and with (the blue upper curve) a STATCOM installed at location 33 (load node number 65). The effect of the STATCOM on the enhancement of the performance of the study transmission line is shown in Fig. 5.
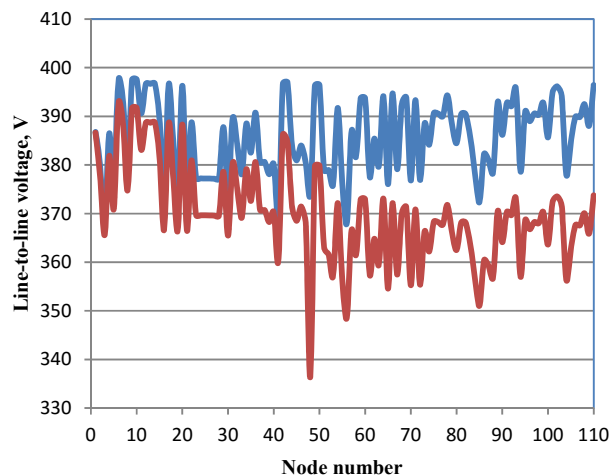

Fig. 5 Line-to-line voltages of the load nodes as expected in 2020 without and with a STATCOM installed at different nodes

IV. CONCLUSIONS

A case study of using STATCOM to enhance the performance of Al-Qatraneh 33-kV transmission line in Jordan has been studied. The location of the STATCOM has been determined by maintaining minimum voltage drops at the 110 load nodes of the study system. MATLAB/Simulink has been used to model this transmission line and the 110 load nodes. A STATCOM and its location have been suggested to increase the transmission capability of this transmission line and to overcome the overload expected in the year 2020. The annual percentage loading rise has been considered as 14.35%. A graphical representation of the line-to-line and average voltages at different load nodes has been illustrated and analyzed.

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