Improving Voltage Sag of Turbo-Expander Starting in NEKA Power Plant By STATCOM

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Abstract

This paper presents the way of mitigation technique for voltage sag and swell produced by starting of NEKA power plant's Turbo-expander. The performance of the static synchronous compensator was investigated under the starting of turbo-expander and various types of fault conditions. The simulation results, performed by PSCAD/EMTDC software, showed that the static synchronous compensator, has a good in both starting of Turbo-expander and fault cases. Static synchronous compensator can mitigate any sag and swell from the voltage of sensitive load.

Keywords
Turbo-expander; Voltage Sag Compensation; Static Synchronous Compensator (STATCOM).

1. Introduction

The natural gas used in thermal power plants is transferred at high pressure through pipelines. However, due to the need of auxiliary service system consumers to gas at low pressure, its pressure should be lowered at the consumption point by reducing the strain energy in the pressure reduction stations. In most of these stations, the pressure is reduced by throttle valves and the energy of the gas pressure (exergy) is wasted. But, this energy can be converted into a useful energy by a turbo-expander. The high pressure natural gas enters the turbo-expander and comes out at reduced pressure, which in turn puts the generator in rotation. This technology is called pressure inversion into power (PIP).

The privatization of power plants in Iran and plans for higher power generation has resulted suggestion of different solutions for efficient utilization of power plants and reduction of energy consumption in auxiliary service system [1]. Considering the insignificant impact of solutions on the efficiency [1], and the high consumption of the auxiliary service system of thermal power plants, the application of turbo-expander at gas pressure reduction stations of the thermal power plant is an acceptable solution. The advantages of using this solution are discussed in following paragraphs.

This system does not cause environmental pollution and is considered as clean (green) industry [2, 3]. The reduction of gas pressure by turbo-expanders and throttle valves reduces the temperature of the output gas [4]. But, the application of turbo-expanders results in greater temperature drop and it can be used for cooling down different equipments. Although this system, compared to throttle valves, has higher investment, operation and maintenance costs, but due to the energy that is generated without any fuel consumption, it is more economical and the cost of one kWh electricity by this method is less than the cost of same amount of energy generated by the power plant [5].

In order to supply the NEKA power plant auxiliary service system's energy need, a 9.8MW turbo-expander with the equivalent capacity of the auxiliary service system has been provided. Due to The starting current of squirrel-cage induction generator (SCIG) that is connected to the turbo-expander, the system needs a 63MVAR reactive power and this results in severe voltage sag at corresponding bus and outage of sensitive equipments [6, 7]. To remedy this problem, a parallel compensator like static synchronous compensator (STATCOM) with suitable control strategy can be suggested. This will protect the auxiliary service system against the voltage sag.

In this study, Since the STATCOM has many benefits, such as quick response time and better support of voltage instead of other shunt FACTS devices; it was selected for this condition [7]. Compensation for voltage sag in cases of fault occurring in the turbo-expander connecting to the network in three different cases was done by STATCOM.

2. Turbo-expander model

The model of turbo-expander used in this paper is based on [5, 9]. This model calculates the output power of turbo-expander by using inlet and outlet gas specifications without using any look-up tables and thermodynamics software. As shown in [4], turbo-expander works as the regulator valve driving the SCIG via a mechanical shaft.

In order to overcome the fluctuations of mass flow-rate and pressure, caused by change in ambient temperature and gas consumption, at low values of power, synchronous generator (due to presence of excitation system) is used. But, in high-rate power, by using high-inertia SCIG, fluctuations are ineffective and network synchronization improved also it eliminates the cost of generator excitation system [4].

Since the aim of this paper is investigating the voltage sag associated with turbo-expander starting, the corresponding torque produced by turbo-expander is modelled as generating torque of SCIG.

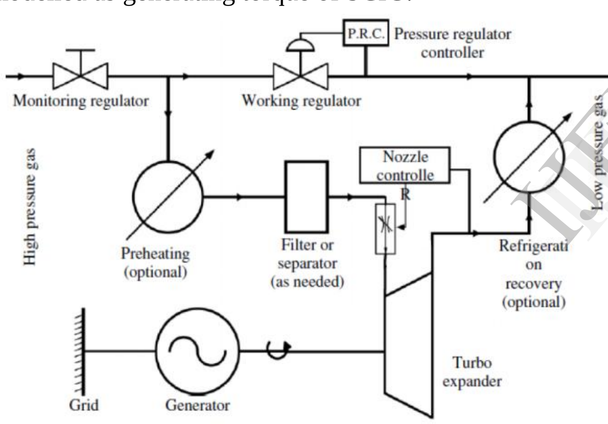


Fig. 1 Schematic representation of gas regulating station and TE installation topology [5]

3. STATCOM compensator

The STATCOM is modeled as 6-pulse converter containing GTO inside the voltage source converter and a capacitor as DC source voltage connected to the network through a 3-phase transformer.

The reactive power exchanged between the converter and the network can improve the sensitive load voltage against the voltage disturbances. As shown in Fig. 2 the control system of STATCOM based on a proportional-integral (PI) controller gets feedback of 3-phase currents and voltages [8, 10].

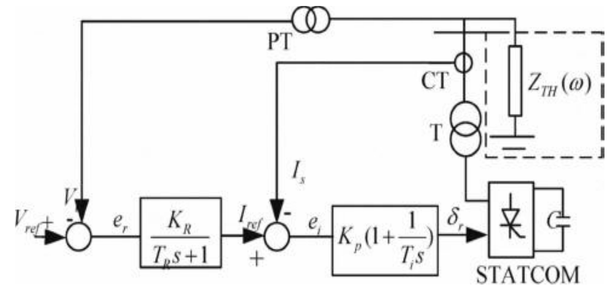


Fig. 2 *Schematic diagram of STATCOM controller*

4. Simulation and comparison results

To verify the feasibility of the STATCOM, PSCAD/EMTDC simulation has been performed for three follow the cases.

a. Compensating in case of 3-phase to ground fault presence in the network and the absence of turbo-expander.

b. Compensating in case of fault absence and presence of turbo-expander.

c. Compensating in case of 3-phase to ground fault and turbo-expander.

Fault start at t =1s with 0.75s duration. Where the schematic diagram of the implemented system was shown in Fig. 2. Also the parameters of turbo-expander are mentioned in table 1.

Table 1 *Turbo-expander*

RMS Phase voltage	V=11.545 kV
RMS Phase current	I=0.02804 A
Base angular frequency	ω=314 rad/s
Power factor	0.85
Efficiency	0.98
Number of poles	4
Inertia J	10 $kg.m^2$
Mechanical damping	0.008 P.U

4.1. STATCOM results

STATCOM as a shunt facts device for determining the compensating capability for sensitive load voltage are testing. In figures below 3 cases above in real network and the presence of STATCOM are tested and STATCOM information is as follows in table 2.

Table 2 *STATCOM information*

Storage	C=100μF,B_c=67.5 (1/Ω)
Bus voltage	V=25kv
PLL	G_p=50,G_i=50,V=100v
GTO	R_{on}=0.005Ω,R_{off}=1e8Ω R_{snuber}=5000Ω,C_{snuber}=0.05μf

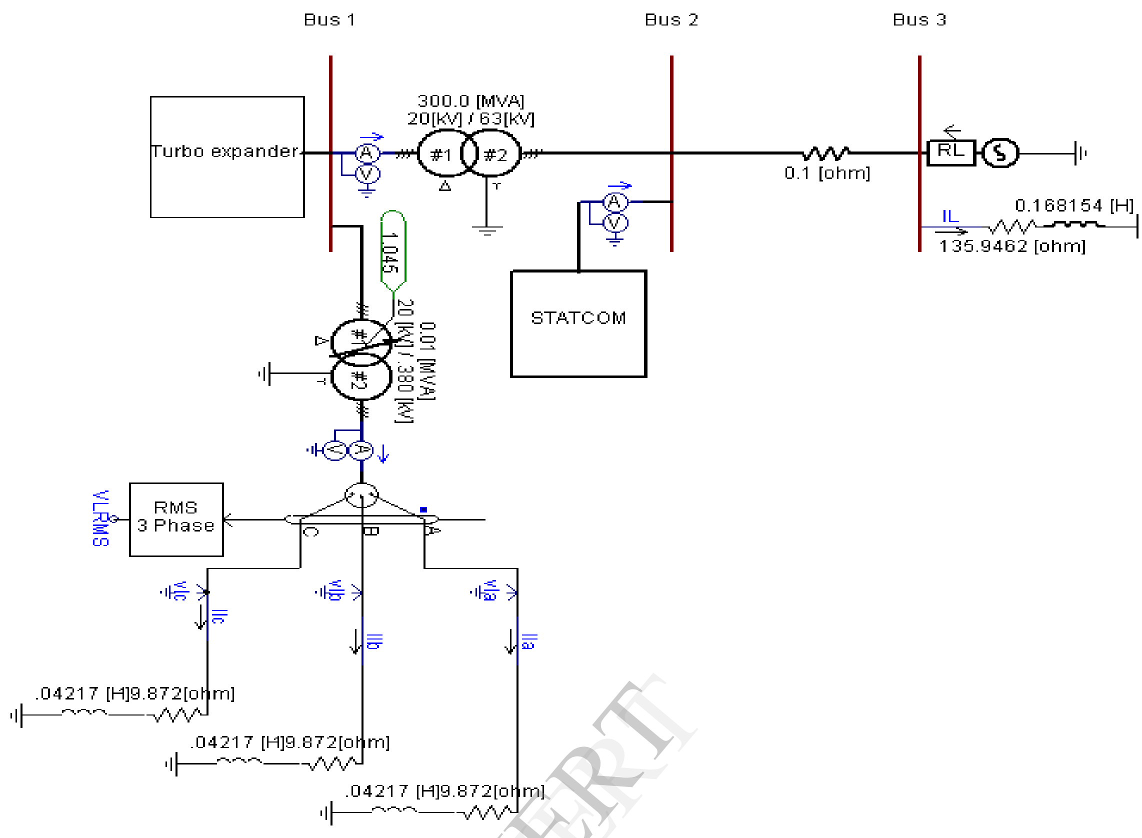


Fig. 3 *Sensitive load voltage in presence of STATCOM*

Table 2 *STATCOM information*

Storage	C=100μF,B_c=67.5 (1/Ω)
Bus voltage	V=25kv
PLL	G_p=50,G_i=50,V=100v
GTO	R_{on}=0.005Ω,R_{off}=1e8Ω R_{snuber}=5000Ω,C_{snuber}=0.05μf

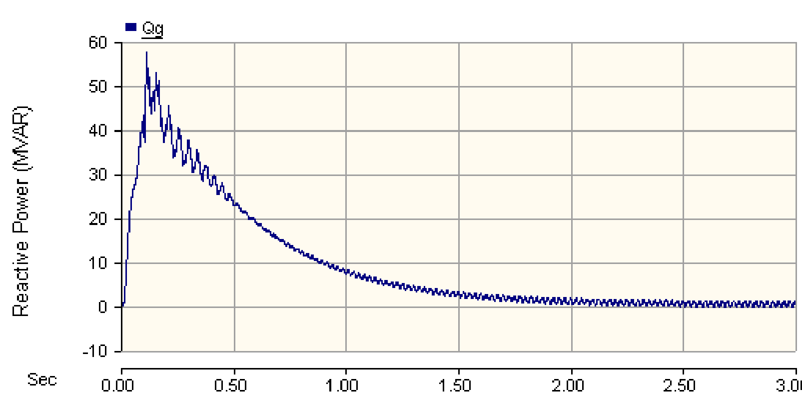
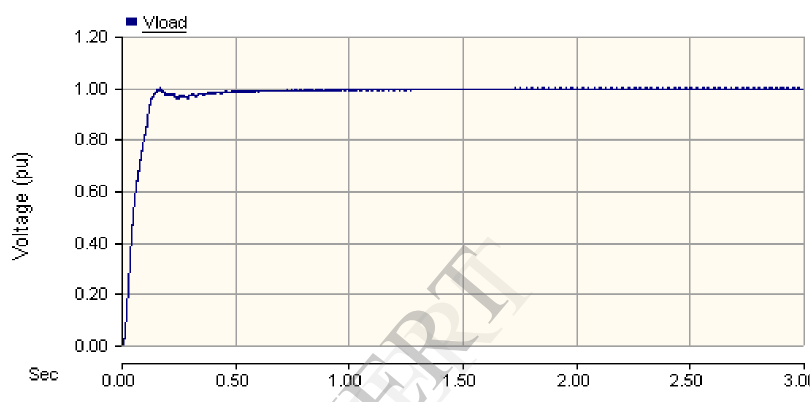


Fig. 4 *generated reactive power*

a.

b.



c.

Fig. 5 *Sensitive load voltage with STATCOM compensator*

a) Compensating in case of 3-phase to ground fault presence in the network and the absence of turbo-expander

b) Compensating in case of fault absence and presence of turbo-expander

c) Compensating in case of 3-phase to ground fault and turbo-expander

4.2 Comparison Results

From the simulation results above we can see that the sensitive load voltage with STATCOM and mentioned information in table 2 can be compensated immediately, remove any sag and swell from the voltage profile as shown in Fig. 5 and improve network power quality. STATCOM injection apparent power for sag correction STATCOM can remove deep sag for both sides without injecting active power to the network. STATCOM does not need an external DC power supply for inverter DC bus voltage.

5. Conclusion

In this study by using the STATCOM, According to installed system in NEKA power plant we can protect sensitive load voltage and remove any sag and swell, at the starting moment of Turbo-expander and fault condition. Because of fast and accurate performance of STATCOM according to Fig. 5 any sag and swell at PCC which causes serious damage to sensitive loads was resolved by STATCOM. The overall results show that STATCOM is ideally appropriate compensator for this problem.

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