World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 5.924

STUDY ON REACTIVE POWER COMPENSATION OF METHEHARA SUGAR FACTORY USING D-STATCOM

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Article Received on 14/10/2019 **Article Revised on 04/11/2019** **Article Accepted on 25/11/2019**

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ABSTRACT

Reactive power compensation is the technique or practice used to control the reactive power circulation in the power system. It can be done by either absorbing or injecting the reactive power where it is needed. Distributed Static synchronous compensator (D-STATCOM) devices offer many potential benefits for power system operation to control the reactive power flow in the system. This paper focuses on the study of reactive power compensation of Metehara Sugar Factory in Ethiopia. As the collected data shows that, the factory is affected by overloading and low power factor problems. The Matlab simulation model of a Metehara Sugar Factory with and without D-STATCOM is implemented. The simulation results show that, without connecting D-STATCOM the power factor is 0.627 and per phase root mean square (RMS) voltage magnitudes are 182 v, 192 v and 198 v. This shows that RMS voltage and power factor of the loads are faced below international standard. By connecting D-STATCOM in parallel with the load side, the per phase magnitude of RMS voltage becomes 212 v, 218 v and 242 v. The RMS voltage after connecting the proposed device becomes in the range of standard value. D-STATCOM is a reactive power compensating device which injects and absorbs reactive power to support bus voltages in a distribution system.

KEYWORD: FACTS, D-STATCOM, Reactive power, Power flow, RMS voltage.

1. INTRODUCTION

Reactive power compensation is defined as the administration of reactive power to ameliorate the production of Alternating Current (AC) in an electrical network. The idea of reactive power compensation encompasses an extensive and divergent field of both system and consumers' problems, mostly connected with power quality matters since most power quality issues can be resolved with appropriate control of reactive power.[1] Reactive power imbalance occurs when the system is faulted, heavily loaded and during voltage fluctuation. Reactive power balance can be regained by connecting a device to the transmission line which can inject or absorb reactive power based on system requirement. One of the most important reactive power sources is FACTS (Flexible A.C transmission system) device. FACTS may be defined as a power electronic based semiconductor device which can inject or absorb reactive power in a system as per requirement. This device allows "Flexible" operation of an AC system without stressing the system. In the literature, the performances of several FACTS devices like, FC-TCR, STATCOM, TCSC, SSSC and UPFC are analyzed.[2, 3]

The D-STATCOM is a shunt connected FACTS device which supplies reactive power to the load to improve the voltage stability of the load busses. The D-STATCOM in multi bus system is capable of reducing the losses and improving the voltage regulation. The improvements and benefits that can be gained using a STATCOM include the following:

- Rapid response to system disturbances.
- Provides smooth voltage control over a wide range of operating conditions.
- Dynamic voltage control in transmission and distribution systems;
- Power oscillation damping in power transmission systems;
- Transient stability improvement;
- Ability to control not only reactive power but, if needed, also active power (with a DC energy source available)
- A small footprint, due to the replacing of passive banks by compact electronic converters;
- Modular, factory built equipment, reducing site works and commissioning time;.[5]

As the reactive power compensation is the technique or practice used to control the reactive power circulation in the power system which can be done by either absorbing or injecting when it is needed. If the reactive power is not properly controlled, can lead to many issues in the voltage magnitude, efficiency and quality of the power system. The reactive power management problems also exist in a distribution network and can be compensated using power electronics devices like D-STATCOM.

This paper focuses on reactive power compensation of Metehara sugar factory using Distributed Static Synchronous Compensator (D-STATCOM) device. It is the largest sugar factory among Ethiopian sugar industries which is located in the north east of Addis Ababa. As the collected data shows that, the factory is affected by overloading and low power factor problems. The overloading condition leads to reduce the RMS voltage below the international accepted standard values. To support the bus voltage on the load side and improve the power factor of the factory, Static Synchronous Compensator (D-STATCOM) is selected and the study encompasses on those problems and their solution.

2. METHODOLOGY

2.1 Data Collection

The data has been collected from **Metehara sugar factory** by two ways, one by interviewing the factory worker and another by measuring secondary side of the transformer using the power quality analyzer. The factory got electric power from three sources. These are from the Ethiopian electric power utility, diesel generators and from steam. Ten transformers in the factory send power to different loads. Most of the loads are inductive and has a lagging power factor. The tables 1-7 shows the different data gained from the Metehara sugar factory site.

Table 1 Active power (P) in KW.

Phase	R	Y	B	P total
Reading 1	54.7	58.1	57.3	170
Reading 2	48.5	51.4	50.3	150
Average	52	55	54	160

Table 2 Reactive power (Q) in Kvar.

Phase	R	Y	B	Q total
Reading 1	70.1	68.0	73.2	211
Reading 2	70.6	69.0	73.4	213
Average	70.35	68.5	73.3	212

Table 3 Apparent power (S) in KVA.

Phase	R	Y	B	S total
Reading 1	88.9	89.4	92.9	271
Reading 2	85.6	88.1	89.0	261
Average	87.25	88.75	90.95	266

Table 4 Power factor (PF).

Phase	R	Y	B	PF avrg
Reading 1	0.6155	0.6500	0.6163	0.6272
Reading 2	0.5520	0.5932	0.5670	0.5806
Average	0.58375	0.6216	0.59165	0.6039

Table 5 Voltage (V) in volt.

Phase	R	Y	B	V average
Reading 1	228.71	226.30	228.43	227.81
Reading 2	228.33	226.29	228.33	227.75

Table 6 Current (I) in ampere.

Phase	R	Y	B	I average
Reading 1	388.6	395.2	406.7	398.6
Reading 2	374.6	380.3	389.7	381.5

Table 7 General Load profile of the factory.

Active power (KW)	Reactive power (Kvar)	Apparent power (Kva)	Power factor (PF)	Frequency (HZ)	V_{rms} (v)	I_{rms} (A)
170	211	271	0.6272	52.517	227.8	396.8

2.2 Power Transmission

The basics of power transmission in a simple system are shown below:

Figure 1 Model of a simple transmission system.

Figure 1 shows a simplified power transmission system with two buses which are connected to each other by a transmission line, which is assumed lossless and has only a reluctance X. V1∟δ and V2∟0 represent the sending end and receiving end voltages with phase angle δ. P2 and Q2 represent the active and reactive power at the receiving end. The current in the transmission line can be written as:

$$I = \frac{V_1(\cos\delta + j\sin\delta) - V_2}{jX} \quad (2.1)$$

The complex power at the receiving end is:

$$S_2 = P_2 + jQ_2 = V_2.I^* = V^2 \left(\frac{V_1(\cos\delta + j\sin\delta) - V_2}{jX}\right)^* = \frac{V_1 V_2}{X}\sin\delta + j\left(\frac{V_1 V_2 \cos\delta - V_2{}^2}{X}\right) \quad (2.2)$$

The active power and reactive power at the load area:

$$P_2 = \frac{V_1 V_2}{X}\sin\delta = P_{max}\sin\delta;\ Q_2 = \frac{V_1 V_2 \cos\delta - V_2{}^2}{X} \quad (2.3)$$

The complex power at the sending is:

$$S_1 = P_1 + jQ_1 = V_1.I^* = V^{1.} \left(\frac{V_1(\cos\delta + j\sin\delta) - V_2}{jX}\right)^* = \frac{V_1 V_2}{X}\sin\delta + j\left(\frac{V_1{}^2 - V_1 V_2 \cos\delta}{X}\right) \quad (2.4)$$

The active power and reactive power at the sending end are:

$$P_1 = \frac{V_1 V_2}{X}\sin\delta = P_{max}\sin\delta;\ Q_1 = \frac{V_1{}^2 - V_1 V_2 \cos\delta}{X} \quad (2.5$$

From equations (2.3) and (2.5), active power at both the ends is same, since the line is considered lossless. Active power can reach its maximum when δ = 90̊. Reactive power mainly depends on the voltage magnitudes and it always flows from the highest to the lowest voltage bus.

3. RESULTS AND ANALYSIS

The study is done by modelling the electrical supply of METEHARA sugar factory from source to load demand. After modelling, a simulation study is first done without connecting a reactive power compensating device. And after observing the result, a Distributed Static Synchronous Compensator (D-STATCOM) is connected in parallel with the load side and their result is observed and its interpretation is also constructed as below. Here the power factor is also improved from 0.603 to 0.85 after connecting D-STATCOM.

3.1 Simulation Study without D-Statcom

The Matlab simulation model of the METEHARA sugar factory without D-Statcom is shown in Figure 2 with its output result. The model consists of a three phase power source which feeds the factory, a step down transformer and an RL load. The figure below shows the model of the system in Matlab Simulink.

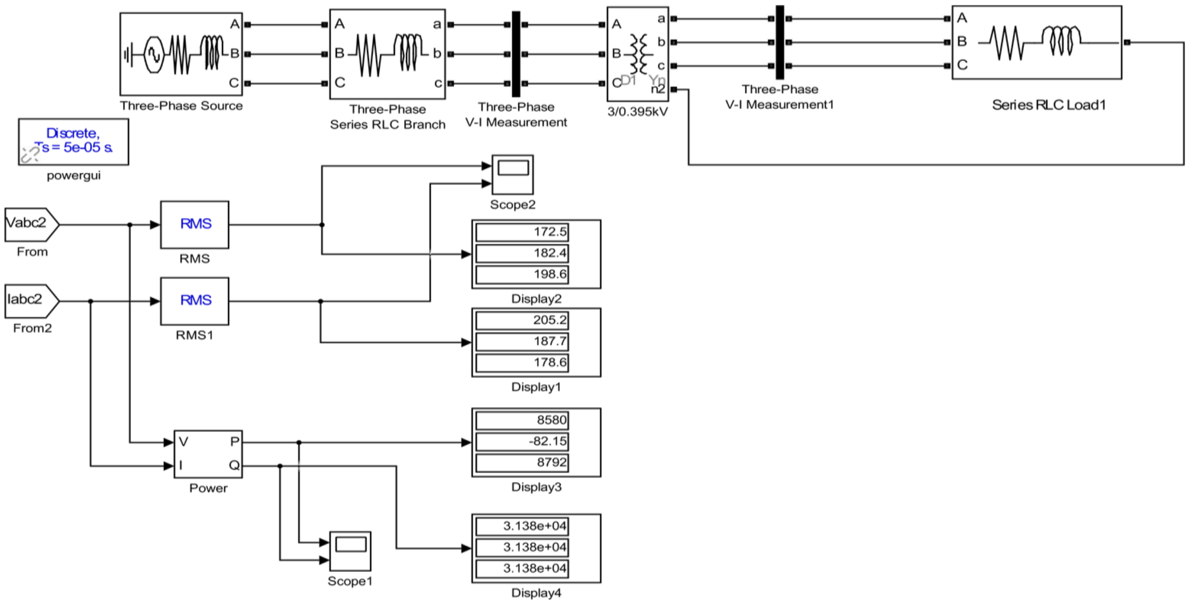


Figure 2 Simulation model of the factory without D-STATCOM.

3.1.1 RESULT DISCUSSION

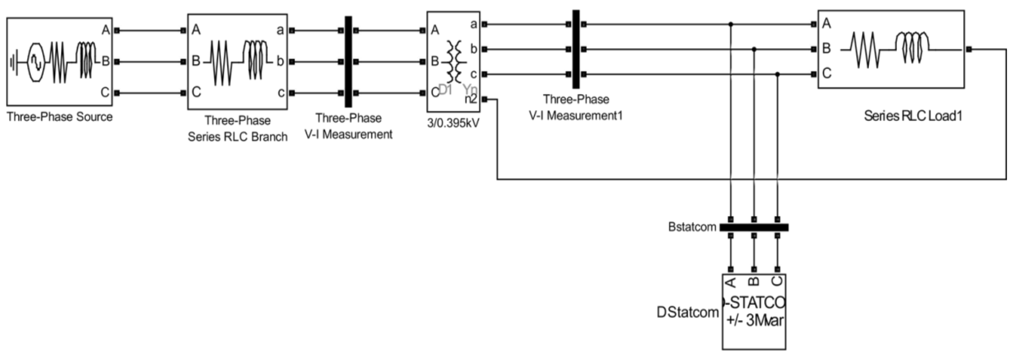
From the simulation the display records the RMS voltage magnitude of the load. As the display shows the RMS voltage magnitude per phases are 182 v, 192 v and 198 v. From the result the RMS voltage of the loads is faced below the standard value of voltage. Table 8 summarizes this discussion without connecting the recommended device.

Table 8 Voltage (V) and reactive power (Q) without D-STATCOM.

Parameter	R	Y	B	Average
RMS voltage	212.5	218.2	242.4	224.4
Reactive power	31680	31680	31680	31680

3.2 Simulation Study with D-Statcom

The Matlab simulation model of a **Metehara** sugar factory with the proposed solution (D-STATCOM) is shown in Figure 3 with its output result.



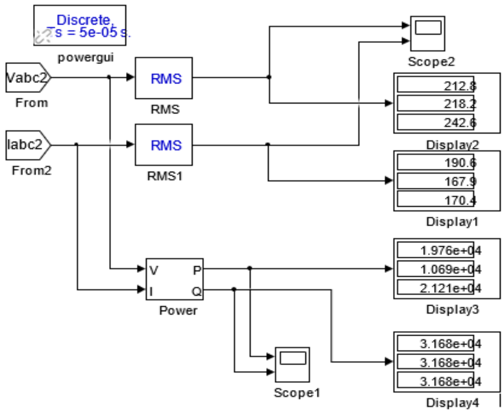


Figure 3 Simulation model of the factory with D-STATCOM.

3.2.1 RESULT DISCUSSION

After connecting a distribution static synchronous compensator (D-STATCOM) in parallel with the load, the per phase magnitude of RMS voltage lies at the limit of standard value. The RMS voltage after connecting the proposed device become 212 v, 218 v and 242 v of each phase respectively. The injected reactive power from the device is about 300 var. Table 9 summarizes this discussion.

Table 9 Voltage (V) and reactive power (Q) with D-STATCOM.

Parameter	R	Y	B	Average
RMS voltage	172	182.4	198.6	184.5
Reactive power	31380	31380	31380	31380

4. CONCLUSION AND FUTURE WORK

Whenever an overload happens on the load side, the bus voltage magnitude decreases and this leads to malfunction of equipment’s. **Metehara Sugar Factory** is one of the largest industries in Ethiopia but sometimes it is facing an overload problem and has a low power factor. The reactive power compensation device called D-STATCOM solves the overload problem by injecting and absorbing reactive power to support the bus voltage magnitude. The device here also uses to improve the power factor of 0.603 and which is now becoming 0.85. This study only focused on increasing the bus voltage because of overloading problem and improving the power factor due to lack of reactive power management by using the recommended device., But as shown above, there is unbalancing between the bus voltage magnitudes. The next study will be done on balancing these unbalanced voltage magnitudes by further analyzing the problems with their solution.

ACKNOWLEDGEMENTS

The authors wish to thank all our friends, whom directly or indirectly have contributed to complete this study.

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