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POWER FACTOR IMPROVEMENT OF THE GLENMORE SUGAR INDUSTRY ELECTRICAL SYSTEM

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ABSTRACT

This research discusses improving the power factor in the Glenmore Sugar Industry electrical system. Variations in inductive loads can cause low power factors. This impacts large currents and high reactive power so that a blackout can occur in the Glenmore Sugar Industry electrical system. Low power factor is corrected with the most effective Costum Power Devices, namely Static Var Compensator (SVC) and Static Synchronous Compensator (STATCOM). The evaluated and corrected load buses are those with low power factor. The simulation results show the application of STATCOM can increase the power factor with reactive power values in the range from +4.9 to –0.994 MVAR, +1.6 to -0.32 MVAR and +3.9 to -0.7875 MVAR. In the lowest results of SVC, the power factor increased from 0.76 to 0.86 with reactive power values in the range from + 1.6 to –0.64 MVAR. The power factor increased from 0.76 to 0.85 with reactive power values ranging from +4.9 to –1.9 MVAR. And for the highest results, the power factor increased from 0.82 to 0.92 with reactive power values ranging from +3.9 to –1.5 MVAR. In addition of SVC, it can be reduced on the main buses in the system, which is 30% to 50% of the reactive power of the main bus, which can also minimize the voltage drop of 1%.

Keywords Power Factor; SVC; STATCOM; Reactive Power; Industry.
Paper type Research paper

INTRODUCTION

A good electricity management system is needed in the progress of industry. In industrial electrical systems, load conditions will affect system operation. The many loads were followed by an increase in reactive power due to the large use of inductive loads on the load bus and on the line. Inductive loads can cause low power factor. Inductive loads require not only active power but also reactive power. Inductive loads are created by winding wires (coils) found in various electrical devices such as electric motors, transformers and relays. The reactive power required by this inductive load can decrease the value of cos φ.

The power factor or cos ϕ is the ratio of the active power to the apparent power. Cos ϕ can also be used as a good indicator of the efficiency of the supply system. The greater the power factor, the more effective the electric power distributed [1]. Electrical power savings will be achieved by improving the power factor. As a provider of electricity services, PLN provides a power factor standard for large industries with a value of cos ϕ 0.9. Additional cost will be charged in the payment of electricity from an industry if the electricity consumption operates at a power factor below this value [2].

This research discusses improving the power factor in the Glenmore Sugar Industry electrical system using SVC and STATCOM. The evaluated bus load is the one with the low power factor. The problem of decreasing the power factor at PT. The Glenmore Sugar Industry takes place on the 6.3 kV MV side grid line. On the MV side of 6.3 kV no capacitor is installed. But on the LV 400V side, a capacitor bank (500kVar) has been installed on each line. Cos ϕ which was originally 0.9 dropped to 0.4. The many variations in inductive loads can cause this. To overcome the problem of low cos pi, this research proposes the application of Static Var Compensator (SVC) and Static Synchronous Compensator (STATCOM). SVC and STATCOM are Custom Power Devices new technology based on power electronics whose main role is to increase controllability and power transfer capability in AC systems. This device provides new opportunities in controlling and improving electric power systems [3].

SVC and STATCOM are used in two different application areas[4]. The first area used in transmission systems to control the flow of power and improve system stability. The second area is used in industrial distribution systems. The main task is to improve power quality, especially reactive power compensation, suppress voltage imbalances, and suppress flicker effects for dynamic loads [5].

Dominik Szabol (2014) researched SVC control as a power factor correction. This study describes the design and modeling of SVC. The SVC model is designed to be implemented on a 22 kV 3-phase network. The function unit control regulates SVC (Qsvc) reactive power compensation automatically by PID. The results of this study prove that SVC is able to compensate for low power factor (both lagging and leading) in each phase independently and automatically in a very short time. Suhail also conducted a similar research in 2016, his research discusses reactive power compensation in solar power plants using SVC and STATCOM. The method used is load flow analysis and stability analysis. The analysis results will be compared which equipment gives the best effect for the system [6].

Based on the problems and descriptions mentioned above, this study aims to improve the electric power factor in the PT system. Glenmore Sugar Industry with SVC and STATCOM. The calculation and modeling of the system will use the Newton Raphson method in MATLAB and the performance of the system and its improvements will be simulated with MATLAB – PSAT and ETAP software.

METHOD

A. Power Factor Improvement

Power factor (Cos φ) can be defined as the ratio between the active power (Watts) and the real power (VA) used in an AC circuit or the phase angle difference between V and I which is usually expressed in terms of cos φ.

$$\begin{aligned}\text{Power factor} &= \text{Active power (P) / Real Power (S)}\\ &= \text{KW / KVA}\\ &= \text{V I COS } \varphi \text{ / V I}\\ &= \cos\varphi \qquad (1)\end{aligned}$$

Power factor (Lagging)
Lagging power factor is a state of power factor with the following conditions [7]:
1. Current (I) lags behind voltage (V)
2. V precedes I by angle φ

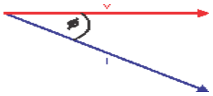


Figure 1. Current Lagging Voltage by Angle φ

From Figure 1, it can be seen that the current lags behind the voltage, so the reactive power precedes the real power, meaning that the load requires or receives reactive power from the system.

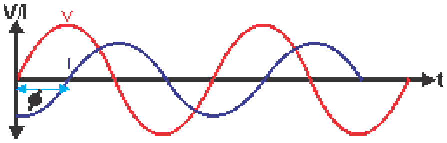


Figure 2. Power Factor Wave Lagging

Power factor (Leading)
The power factor precedes the state of the power factor with the following conditions:
1. Current (I) precedes voltage (V)
2. Voltage (V) lags behind Current (I) by an angle *φ*

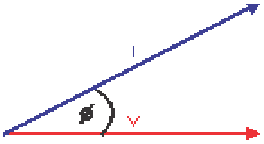


Figure 3. Current Leads Voltage By Angle φ

The power factor has a value range between 0 – 1 and can also be expressed in percent. The power factor is good when it is close to one.

$$\text{Tan} = \text{reactive power (Q)/ active power (P)} = \text{kVAR/kW} \qquad (2)$$

Since the active power component is generally constant (kVA and kVAR components change according to the power factor), it can also be written as follows:

$$\text{Reactive Power (Q)} = \text{Active Power (P) x Tan } \varphi \qquad (3)$$

B. *Reactive Power Control*

In the absence of compensation, the type of line is an inductive load where the current is lagging against the voltage. The system load line is depicted as shown in Figure 4, if the system load is more inductive, the current is getting left behind while Q is also getting bigger, meaning that it is absorbing more reactive power, on the other hand, if it is more capacitive, the current is leading to the voltage V and supplying reactive power Q [8].

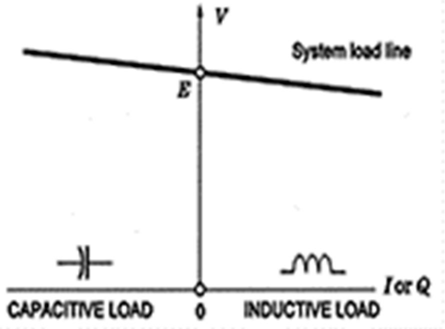


Figure 4. System Load Line

$$\Delta V = E - V = Z_S . I \qquad (4)$$

I= load current ; E= reference voltage; Zs = line impedance ; V = voltage drop

The complex power of the load per phase is defined by the equation [9] :

$$I = \frac{P - jQ}{V} \qquad (5)$$

And if V=V + j0 taken as the reference phasor , we can write

$$\Delta V = \Delta VR \qquad (6)$$

$$\frac{\Delta V}{V} = \frac{X_s Q}{V^2} \approx \frac{Q}{S} \qquad (7)$$

$$V \approx \left(1 - \frac{Q}{S}\right) \qquad (8)$$

This means that changing the value of Q will affect the Bus voltage. The greater the value of Q supplied, the voltage V will also increase [10].

Static Var Compensator (SVC)

Static VAR Compensator (SVC) is a power electronic device arranged in parallel to regulate power flow and improve transient stability of the network system [11]. SVC regulates the voltage at each terminal by regulating the amount of reactive power injected or absorbed from the power system. The SVC generates reactive power when the system voltage is low (Capacitive SVC). When the system voltage is high, the SVC absorbs reactive power (Inductive SVC). The regulation of reactive power variation is done by switching the capacitor bank and 3-phase inductor bank connected to the secondary side of the transformer. The on and off condition of the capacitor bank is regulated by a thyristor switch (Thyristor Switched Capacitor or TSC). The on and off conditions of the reactor are regulated by the Thyristor Controlled Reactor (TCR). The following figure shows the SVC equivalent circuit with a constant capacitor current:

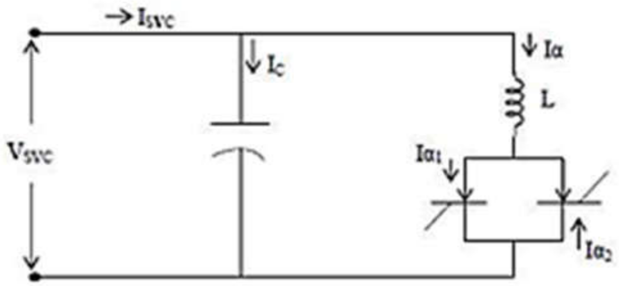


Figure 5. SVC equivalent circuit with constant capacitor

V_{SVC} = Voltage at SVC
Iα1 dan Iα2 = Current through the Thyristor switch
C = Capasitor
L = Induktor
I_{SVC} = The total current through SVC

The amount of reactor current is determined by setting the ignition angle of the thyristor switch. The amount of current taken by SVC is Ic + Iα. The current condition of Ic is constant (fixed capacitor), while the current through the reactor is regulated by the thyristor switch which produces components Iα1 and Iα2. While 1 and 2 in the figure are the ignition of thyristor 1 and thyristor 2.
By setting 1 and 2 then Iα1 and Iα2 are also set, then Iα = Iα1 + Iα2 is also set. As shown in the figure, Iα is the current through the reactor. The total current through SVC is Ic + Iα,
By selecting the correct reactor value and setting it via a thyristor switch. Thus the SVC can be set to inject or absorb reactive power from the system [12].

STATCOM (Static Synchronous Compensator)
STATCOM (Static Synchronous Compensator) is a shunt device from FACTS (Flexible AC Transmission System) which consists of electronic power devices to regulate power flow and improve transient stability of the power system. STATCOM regulates terminal voltage regulation by generating or absorbing reactive power from the system. STATCOM generates reactive (capacitive) power if the system voltage is lower. STATCOM absorbs reactive (inductive) power if the system voltage is higher. Variation of reactive power is regulated by VSC (Voltage Source Converter) which is connected to the secondary side of the transformer [13].
STATCOM is a tool for compensating reactive power which is connected in parallel and can generate and/or absorb reactive power and its output can be varied to control the parameter specifications of the electric power system. STATCOM is generally a solid-state switch that can generate or absorb real or reactive power. STATCOM consists of several parts, namely VSC (Voltage Source Converter), produces a three-phase ac voltage. The dc voltage is provided by an energy storage capacitor [14].

C. Determination of Capacitance Compensator

- Determination of SVC Capacitance (Static Var Compensator)
  Based on the nominal power factor value of the system and the desired value, then Q (reactive power) can be obtained by:
  kVAR before the addition of SVC (Static Var Compensator):
  Q1= P Tan 1 (9)
  desired kVAR with value PF=0.9
  Q2= P Tan 2 (10)

So that Q = Q1 – Q2 (11)
From the equation, the power factor improvement can be analyzed.
The KVAR rating of SVC is determined by equation [15]:

$$\Delta V = \frac{\Delta Q}{S_{SC}}$$

KVAsc = KVA Base x (100/x%)
(the value of x is obtained from the network data sheet)

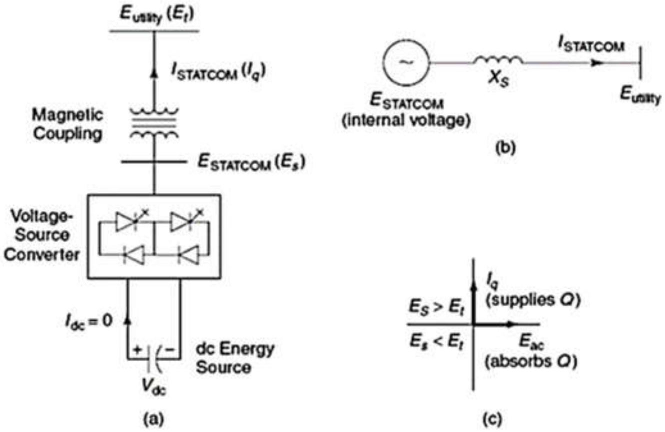


Figure 6. STATCOM working principle diagram
(a) power circuit; (b) equivalent circuit; and (c) power change.

Then the determination of the inductive and capacitive reactive power rating is carried out by calculating according to the equation:

- The limiting value of V on capacitive reactive power is V = 5%, then:
  Q -> Qc = V x KVAsc
- The limiting value of V on inductive reactive power is V = 2%, then:
  Q -> QL = V x KVAsc
- Determination of STATCOM Capacitance

The equation determines the KVAR rating of STATCOM:
KVAsc = KVA Base x (100/x%)
(the value of x is obtained from the network data sheet)

Then the determination of the inductive and capacitive reactive power rating is carried out by calculating according to the equation:

- The limiting value of V on capacitive reactive power is V = 5%, then:
  Q -> Qc = V x KVAsc
- The limiting value of V on inductive reactive power is V = 1%, then:
  Q -> QL = V x KVAsc

D. Data Retrieval

This resarch uses data from the Glenmore Sugar Industry electricity network in 2020. The single line diagram of the Glenmore Sugar Industry electricity network is presented in Figure 5.1. Glenmore Sugar Industry is a growing industry that has a voltage capacity of 20kV/6.3 kV in the MV system and 0.4 KV in its LV system.

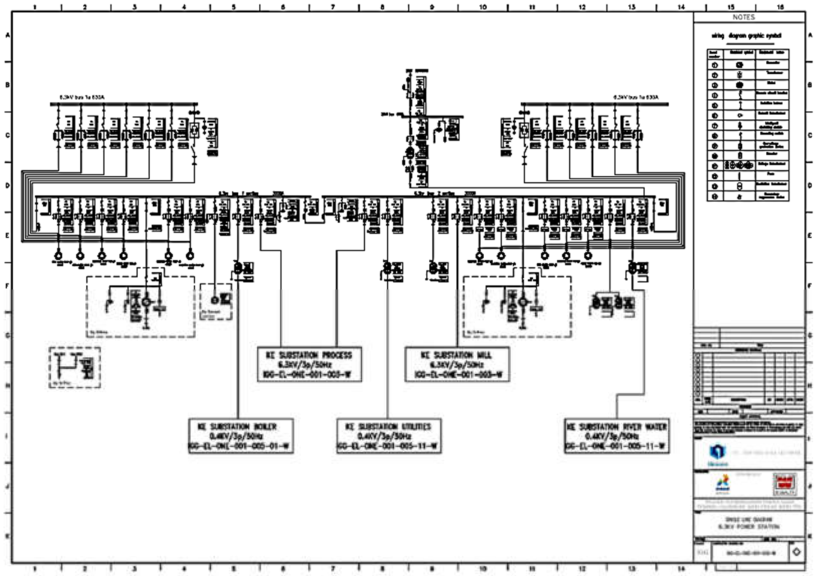


Figure 7. Single Line Diagram of Glenmore Sugar Industry

Based on the picture, the load flow will be simulated and analyzed to see which part of the load bus has a low power factor value.

TABLE I. POWER FLOW DATA ELECTRICITY SYSTEM OF GLENMORE SUGAR INDUSTRY

Bus	ID	Rating	Rated KV	% PF
Bus 15	BOILER	712 KVA	0,4	95
Bus 34	CANE PREP	640 KVA	0,4	95
Bus 113	CC1	800 kW	3,3	76
Bus 114	CC2	800 kW	3,3	76
Bus 6	FEED WATER PUMP #A	450 kW	6,3	86
Bus 7	FEED WATER PUMP #B	450 kW	6,3	86
Bus 23	FEED WATER PUMP #C	450 kW	6,3	86
Bus 9	FORCE DRAFT FAN #1	250 kW	6,3	76,5
Bus 25	FORCE DRAFT FAN #2	250 kW	6,3	82
Bus 112	HDHS	2500 kW	3,3	90
Bus 8	INDUSCHE DRAFT FAN #1	400 kW	6,3	76,3
Bus 24	INDUSCHE DRAFT FAN #2	400 kW	6,3	76
Bus 11	INJECTION WATER PUMP #A	430 kW	6,3	78,8
Bus 12	INJECTION WATER PUMP #B	430 kW	6,3	82
Bus 21	INJECTION WATER PUMP #C	430 kW	6,3	82
Bus 20	INJECTION WATER PUMP #D	430 kW	6,3	82
Bus 110	MILL 1	880 kW	0,69	82,7
Bus 111	MILL 2	880 kW	0,69	86
Bus 115	MILL 3	880 kW	0,69	86
Bus 116	MILL 4	880 kW	0,69	86
Bus 27	PERUM 1	11 KVA	0,4	95
Bus 28	PERUM 2	11 KVA	0,4	95
Bus 42	PROSES 1	495 KVA	0,4	95
Bus 43	PROSES 2	396 KVA	0,4	95
Bus 44	PROSES 3	317 KVA	0,4	95
Bus 19	PUPUK	130 KVA	0,4	95
Bus 47	RIVER WATER	101 KVA	0,4	95
Bus 17	UTILITIES	101 KVA	0,4	95

DISCUSSION

Simulation of power factor improvement is applied to the Glenmore Sugar Industry electrical network system based on table 1 data. In Figure 8. shows the PT. IGG electrical network system.

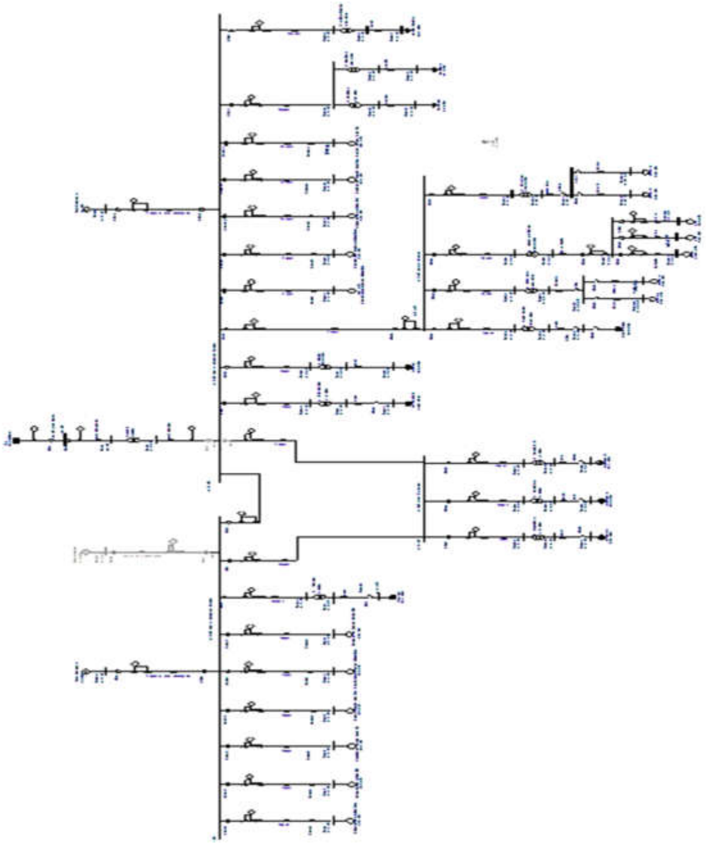


Figure 8. Glenmore Sugar Industry Electrical System

A. *Simulation of Power Factor Improvement in the Glenmore Sugar Industry Electrical Network Before Adding a Compensator*

Based on the data in table 1 and figure 8, the results of the Glenmore Sugar Industry electrical system simulation in conditions before the compensator was installed are shown in figure 9. It can be seen in table 2 that the power factor at several points the load is quite low.

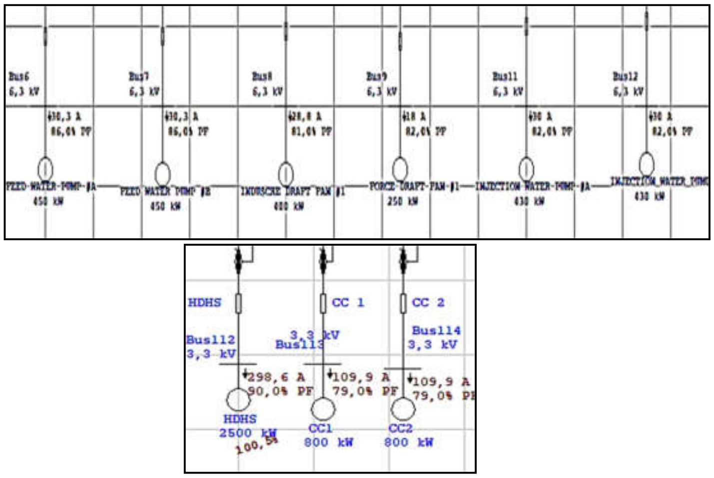


Figure 9. Simulation Results of the Glenmore Sugar Industry Electrical System Load Flow Before Adding the Compensator

TABLE II. POWER FLOW DATA OF GLENMORE SUGAR INDUSTRY

Bus	ID	Rating	Rated KV	% PF
Bus 15	BOILER	712 KVA	0,4	95
Bus 34	CANE PREP	640 KVA	0,4	95
Bus 113	CC1	800 kW	3,3	76
Bus 114	CC2	800 kW	3,3	76
Bus 6	FEED WATER PUMP #A	450 kW	6,3	86
Bus 7	FEED WATER PUMP #B	450 kW	6,3	86
Bus 23	FEED WATER PUMP #C	450 kW	6,3	86
Bus 9	FORCE DRAFT FAN #1	250 kW	6,3	76,5
Bus 25	FORCE DRAFT FAN #2	250 kW	6,3	82
Bus 112	HDHS	2500 kW	3,3	90
Bus 8	INDUSCHE DRAFT FAN #1	400 kW	6,3	76,3
Bus 24	INDUSCHE DRAFT FAN #2	400 kW	6,3	76
Bus 11	INJECTION WATER PUMP #A	430 kW	6,3	78,8
Bus 12	INJECTION WATER PUMP #B	430 kW	6,3	82
Bus 21	INJECTION WATER PUMP #C	430 kW	6,3	82
Bus 20	INJECTION WATER PUMP #D	430 kW	6,3	82
Bus 110	MILL 1	880 kW	0,69	82,7
Bus 111	MILL 2	880 kW	0,69	86
Bus 115	MILL 3	880 kW	0,69	86
Bus 116	MILL 4	880 kW	0,69	86
Bus 27	PERUM 1	11 KVA	0,4	95
Bus 28	PERUM 2	11 KVA	0,4	95
Bus 42	PROSES 1	495 KVA	0,4	95
Bus 43	PROSES 2	396 KVA	0,4	95
Bus 44	PROSES 3	317 KVA	0,4	95
Bus 19	PUPUK	130 KVA	0,4	95
Bus 47	RIVER WATER	101 KVA	0,4	95
Bus 17	UTILITIES	101 KVA	0,4	95

From the results of table 2, then the network is simulated with a compensator. The installation of the compensator is focused on the bus load with a low power factor (shown in table 3)

TABLE III. POWER FLOW DATA ELECTRICITY SYSTEM OF GLENMORE SUGAR INDUSTRY WITH LOW POWER FACTOR

Bus	**ID**	**Rating**	**Rated KV**	**% PF**
Bus 113	CC1	800 kW	3,3	76
Bus 114	CC2	800 kW	3,3	76
Bus 9	FORCE DRAFT FAN #1	250 kW	6,3	76,5
Bus 8	INDUSCHE DRAFT FAN #1	400 kW	6,3	76,3
Bus 24	INDUSCHE DRAFT FAN #2	400 kW	6,3	76
Bus 11	INJECTION WATER PUMP #A	430 kW	6,3	78,8
Bus 12	INJECTION WATER PUMP #B	430 kW	6,3	82
Bus 21	INJECTION WATER PUMP #C	430 kW	6,3	82
Bus 20	INJECTION WATER PUMP #D	430 kW	6,3	82
Bus 110	MILL 1	880 kW	0,69	82,7

From Table 3. Furthermore, the power factor improvement is carried out with SVC and STATCOM compensators.

B. *Simulation of Power Factor Improvement in the Glenmore Sugar Industry Electrical System After Adding a SVC*

- Analysis of Adding SVC Compensator To Improve Power Factor

The KVAR rating of the SVC is determined by the equation:

$$\Delta V = \frac{\Delta Q}{Ssc}$$

KVAsc = KVA Base x (100/x%), where,
Q = magnitude of compensator value
Ssc = short circuit KVA
V = voltage fluctuation

Then the determination of the inductive and capacitive reactive power rating is carried out by calculations according to the equation:

- Bus 6.3 KV, 3000A (FEED WATER PUMP #A to INJECTION WATER PUMP #B)
  KVAsc = (6.3 x 3000) x (100/19) = 99473.6
  MVAsc = 99473.6 / 1000= 99.4736

  The limiting value of V on capacitive reactive power is V = 5%, then:
  Q -> Qc = V x KVAsc = 0.05 x 99.4736 = 4.9 MVAR
  The limiting value of V on inductive reactive power is V = 2%, then:
  Q -> QL = V x KVAsc = 0.02 x 99.4736 = 1.9 MVAR

- Bus 3.3 KV, 1600A (CC1 & CC2)
  KVAsc = (3.3 x 1600) x (100/16.5) = 3200
  MVAsc = 32000 / 1000= 32
  The limiting value of V on capacitive reactive power is V = 5%, then:
  Q -> Qc = V x KVAsc = 0.05 x 32 = 1.6 MVAR
  The limiting value of V on inductive reactive power is V = 2%, then:
  Q -> QL = V x KVAsc = 0.02 x 32 = 0.64 MVAR

- Buses 6.3 KV, 3000A (MILL 1, MILL2, MILL3 & MILL4)
  KVAsc = (6.3 x 3000) x (100/24) = 78750
  MVAsc = 78750 / 1000= 78.75
  The limiting value of V on capacitive reactive power is V = 5%, then:
  Q -> Qc = V x KVAsc = 0.05 x 78.75= 3.9 MVAR
  The limiting value of V on inductive reactive power is V = 2%, then:
  Q -> QL = V x KVAsc = 0.02 x 78.75 = 1.5 MVAR

Based on the results of the calculation of the parameter values Qc and Ql, the simulation results are shown in Figure 10 and Table 4.

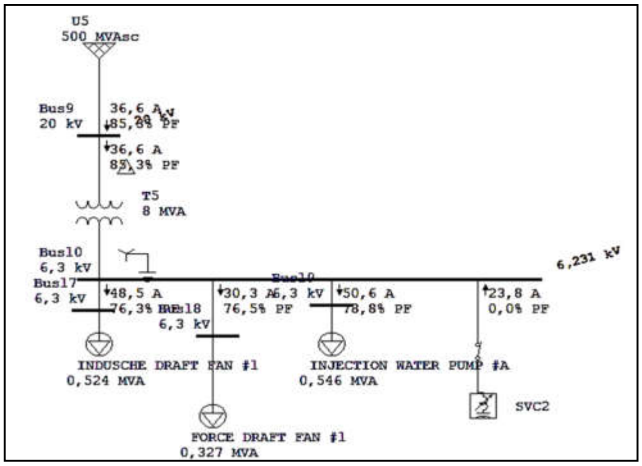


Figure 10. Simulation Results With The Addition Of SVC On Bus 6.3 KV, 3000A (FEED WATER PUMP #A to INJECTION WATER PUMP #B)

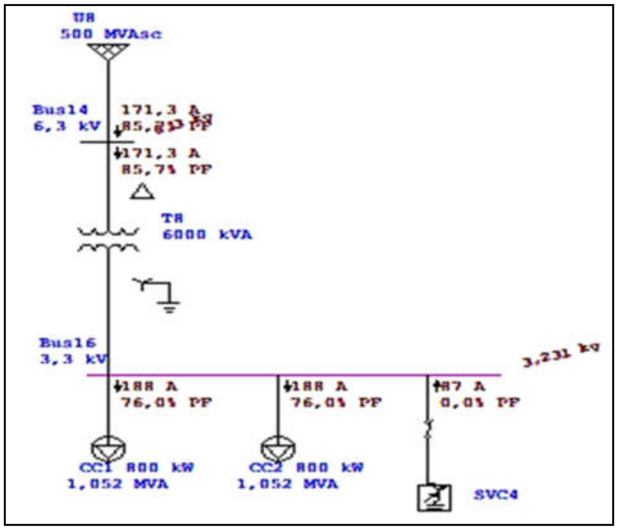


Figure 11. Simulation Results With The Addition Of SVC On Bus 3.3 KV, 1600A (CC1 & CC2)

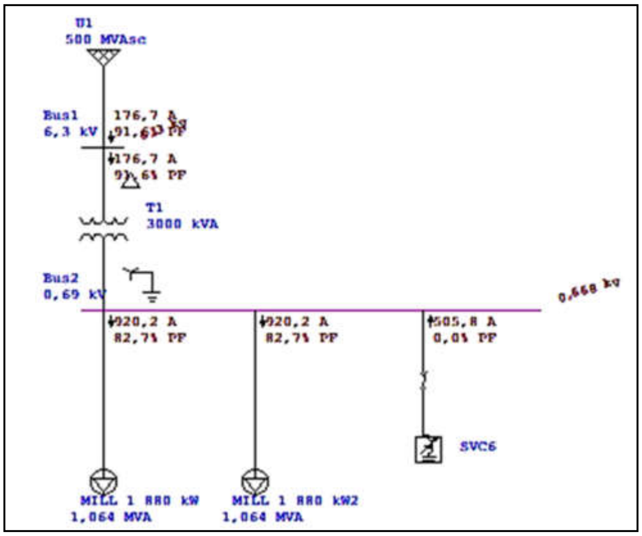


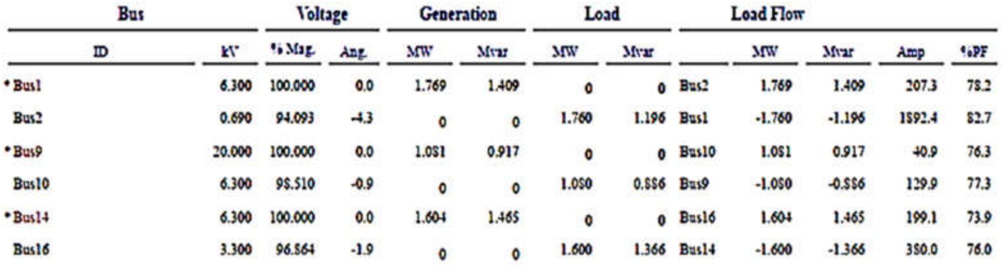
Figure 12. Simulation Results With The Addition Of SVC On Bus 6.3 KV, 3000A (MILL1,MILL2, MILL3 & MILL4)

TABLE IV. POWER FACTOR RESULT WITH COMPENSATOR SVC

Bus	ID	Rating	Rated KV	% PF	% PF After Kompensasi
Bus 113	CC1	800 kW	3,3	76	78,6
Bus 114	CC2	800 kW	3,3	76	78,6
Bus 9	FORCE DRAFT FAN #1	250 kW	6,3	76,5	85,1
Bus 8	INDUSCHE DRAFT FAN #1	400 kW	6,3	76,3	85,1
Bus 24	INDUSCHE DRAFT FAN #2	400 kW	6,3	76	85,1
Bus 11	INJECTION WATER PUMP #A	430 kW	6,3	78,8	85,1
Bus 12	INJECTION WATER PUMP #B	430 kW	6,3	82	85,1
Bus 21	INJECTION WATER PUMP #C	430 kW	6,3	82	85,1
Bus 20	INJECTION WATER PUMP #D	430 kW	6,3	82	85,1
Bus 110	MILL 1	880 kW	0,69	82,7	92,8

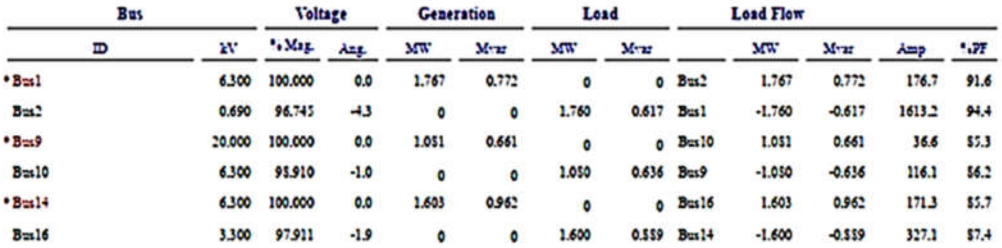
- *Simulation Results of Power Factor Improvement in the Glenmore Sugar Industry Electrical System with the addition of SVC has an effect on reactive power.*

TABLE V. EFFECT OF IMPROVEMENT OF POWER FACTORS ON THE SUGAR INDUSTRY ELECTRICITY SYSTEM GLENMORE ON MAIN BUS REACTIVE POWER BEFORE ADDED COMPENSATOR



Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar		MW	Mvar	Amp	%PF
• Bus1	6.300	100.000	0.0	1.769	1.409	0	0	Bus2	1.769	1.409	207.3	78.2
Bus2	0.690	94.093	-4.3	0	0	1.760	1.196	Bus1	-1.760	-1.196	1892.4	82.7
• Bus9	20.000	100.000	0.0	1.081	0.917	0	0	Bus10	1.081	0.917	40.9	76.3
Bus10	6.300	98.510	-0.9	0	0	1.080	0.886	Bus9	-1.080	-0.886	129.9	77.3
• Bus14	6.300	100.000	0.0	1.604	1.465	0	0	Bus16	1.604	1.465	199.1	73.9
Bus16	3.300	96.864	-1.9	0	0	1.600	1.366	Bus14	-1.600	-1.366	380.0	76.0

TABLE VI. EFFECT OF POWER FACTOR IMPROVEMENT ON THE SUGAR INDUSTRY ELECTRICITY SYSTEM GLENMORE ON MAIN BUS REACTIVE POWER BEFORE ADDED COMPENSATOR



Bus		Voltage		Generation		Load		Load Flow				
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar		MW	Mvar	Amp	%PF
• Bus1	6.300	100.000	0.0	1.767	0.772	0	0	Bus2	1.767	0.772	176.7	91.6
Bus2	0.690	96.745	-4.3	0	0	1.760	0.617	Bus1	-1.760	-0.617	1613.2	94.4
• Bus9	20.000	100.000	0.0	1.081	0.661	0	0	Bus10	1.081	0.661	36.6	85.3
Bus10	6.300	98.910	-1.0	0	0	1.080	0.636	Bus9	-1.080	-0.636	116.1	86.2
• Bus14	6.300	100.000	0.0	1.603	0.962	0	0	Bus16	1.603	0.962	171.3	85.7
Bus16	3.300	97.911	-1.9	0	0	1.600	0.889	Bus14	-1.600	-0.889	327.1	87.4

From tables 5 and 6, it can be seen the effect of power factor improvement on the reactive power of the main bus system. Before adding SVC, the reactive power on Bus 1 was 1409 kVAR, the reactive power for bus 2 was 1196 kVAR, the reactive power for bus 9 was 917 kVAR, the reactive power for bus 10 was 336 kVAR, the reactive power for bus 14 was 1465 and bus 16 had reactive power. of 1366 kVAR. After adding SVC, the reactive power on Bus 1 is 772 kVAR, the reactive power of bus 2 is 617 kVAR, the reactive power of bus 9 is 662 kVAR, the reactive power of bus 10 is 636 kVAR, the reactive power of bus 14 is 962 and bus 16 has reactive power. of 889 kVAR. This shows that the addition of SVC can reduce the value of the main bus reactive power in the network system by 30% to 50% of the original reactive power.

- *Simulation Results of Power Factor Improvement in the Glenmore Sugar Industry Electrical System with the addition of SVC has an effect on Voltage Drop.*

TABLE VII. THE EFFECT OF SVC INSTALLATION ON VOLTAGE DROP

Bus	kV 1	kV2
Bus 2	0,649	0,668
Bus 16	3,197	3,231

After adding SVC, the amount of KV on Bus 2 which was originally 0.649 kV becomes 0.668 kV. The value of KV on Bus 16 was originally 3.197 kV to 3.231 kV. This shows that the addition of SVC can minimize the voltage drop by 1%.

C. *Simulation of Power Factor Improvement in the Glenmore Sugar Industry Electrical System After Adding a STATCOM*

The KVAR determination of STATCOM [8] is determined in the same way as the SVC:

- Bus 6.3 KV, 3000A (FEED WATER PUMP #A to INJECTION WATER PUMP #B)

KVAsc = (6,3 x 3000) x (100/19) = 99473,6

MVAsc = 99473,6 / 1000= 99,4736

For capacitive reactive power limitation ΔV = 5%, so :

ΔQ -> Qc = ΔV x KVAsc = 0,05 x 99,4736 = 4,9 MVAR

While the limit of inductive reactive power ΔV = 1%, so :

ΔQ -> Qc = ΔV x KVAsc = 0,01 x 99,4736 = 0,994 MVAR

- Bus 3.3 KV, 1600A (CC1 & CC2)

  KVAsc = (3,3 x 1600) x (100/16.5) = 3200

  MVAsc = 32000 / 1000= 32

  For capacitive reactive power limitation ΔV = 5%, so :

  ΔQ -> Qc = ΔV x KVAsc = 0,05 x 32 = 1,6 MVAR

  While the limit of inductive reactive power ΔV = 1%, so :

  ΔQ -> Qc = ΔV x KVAsc = 0,01 x 32 = 0,32 MVAR

- Bus 6.3 KV, 3000A (MILL 1, MILL2, MILL3 & MILL4)

  KVAsc = (6,3 x 3000) x (100/24) = 78750

  MVAsc = 78750 / 1000= 78,75

  For capacitive reactive power limitation ΔV = 5%, so :

  ΔQ -> Qc = ΔV x KVAsc = 0,05 x 78,75= 3,9 MVAR

  While the limit of inductive reactive power ΔV = 1%, so :

  ΔQ -> Qc = ΔV x KVAsc = 0,01 x 78,75 = 0,7875 MVAR

The application of STATCOM can increase the power factor with reactive power values in the range from +4.9 to –0.994 MVAR, +1.6 to -0.32 MVAR and +3.9 to -0.7875 MVAR.

CONCLUSION

Based on the research results obtained by simulating the power factor improvement in the Glenmore sugar industry electrical by calculating the parameter values, the following conclusions can be drawn as follows. The placement of SVC and STATCOM is determined from the results of the power flow analysis to determine the low power factor value, which is 0.76 – 0.82. In the application of SVC, for the lowest results the power factor increases from 0.76 to 0.86 with reactive power values in the range from + 1.6 to – 0.64 MVAR. The power factor increased from 0.76 to 0.85 with reactive power values in the range from +4.9 to –1.9 MVAR. And for the highest results, the power factor increased from 0.82 to 0.92 with reactive power values ranging from + 3.9 to – 1.5 MVAR. In the application of SVC on the load bus with a low power factor value, the reactive power value on the main buses in the system is 30% to 50% of the main bus reactive power. The application of SVC on the load bus with a low power factor value can minimize the voltage drop by 1%. The application of STATCOM can increase the power factor with reactive power values in the range from +4.9 to – 0.994 MVAR, +1.6 to -0.32 MVAR and +3.9 to -0.7875 MVAR.

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