Determination of Location and Number of D-STATCOM at the Distribution Network

Shamsul Aizam Zulkifli, Md Zarafi Ahmad, Rohaiza Hamdan and Noor Ropidah Bujal

Abstract – Power quality devices are used to increase/monitor the electric system distribution network. This paper is focus on to determine the location and number of Distribution Static Compensator (D-STATCOM) at 10 bus bar distribution network. By find the optimal number and location of D-STATCOM, it reduced the numbers of D-STATCOM needs in mitigate voltage sag problem. The modal analysis and the time domain simulation are used in determine the best location of D-STATCOM in distribution network.

Keywords: *D-STATCOM, Modal Analysis, recovery time, PSCAD*

INTRODUCTION

Power quality is the ability of utilities to provide electric power without interruption. In recent years, due to increase in critical load an electronic device, customers require high form of power quality than before. The most common power quality problems are voltage sags, harmonics, voltage swell, power interruptions and voltage flicker.

Reactive power compensation is an important issue in electrical power systems where Flexible AC Transmission System (FACTS) devices play an important role in controlling the reactive power flow to the power network. Static Synchronous Compensator (STATCOM) is a member of FACTS family that is connected in shunt with the system. In distribution system, it is also known as D-STATCOM. Recent days, STATCOM commonly located at every critical load in distribution system and it will increase the power quality monitoring cost. Optimal number and location of D-STATCOM will reduce or eliminate power quality problems in distribution system.

D-STATCOM CONFIGURATION

The most basic configuration of STATCOM consists of two-level Voltage Source Converter (VSC) with a DC energy storage device, a coupling transformer connected in shunt with the AC system and the associated control circuits. Fig. 1 shows the schematic diagram of the D-STATCOM. The VSC converts the DC voltage across the storage device into a set of three phase AC output voltages that are in phase and coupled with the AC system through the reactance of coupling transformer. A key characteristic of this controller is that the active and reactive powers exchanged between the converter and the AC system can be controlled by changing the phase angle between the converter output voltage and the bus voltage at the point of common coupling [1]-[4].

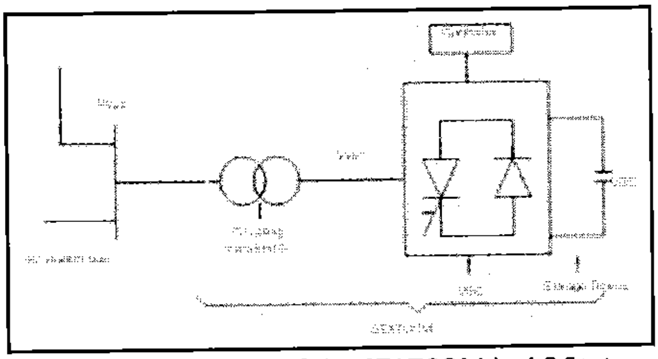


Figure 1 : Connection of the STATCOM in AC System

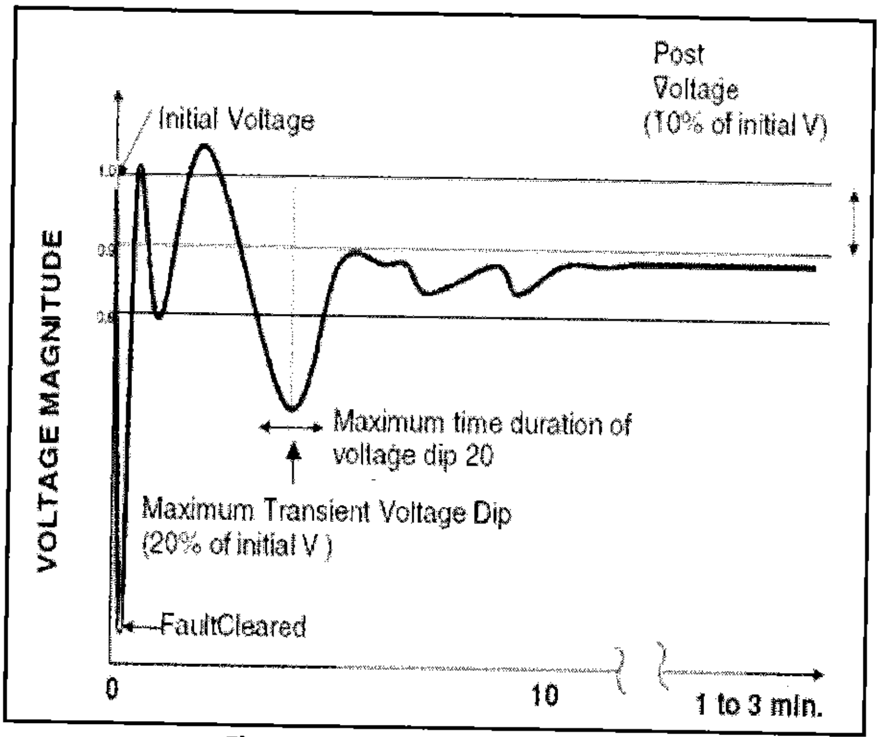


Figure 2 : Voltage Stability Criteria

VOLTAGE STABILITY AND VOLTAGE RECOVERY CRITERIA

Fig. 2 shows the voltage stability criteria where the voltage magnitude should not drop below 80% . As an example if a fault occurs for below 80% of its initial value, and resulting oscillations should not exceed 20 cycles. For 50 Hz system it is about 0.4 s while for the 60Hz system it is about 0.33 s. If this condition occurs it will increase the voltage collapse on the system. Once voltage is recovered, its magnitude should not fall below 0.9 p.u [5]. Fig. 3 shows the Voltage Recovery Criteria. As explain the clearing time for 50Hz system is 0.4 s and this is fall as the ideal for the voltage recovery time. It means that the D-STATCOM that needs to be located must have clearing time for less then 0.4 s.

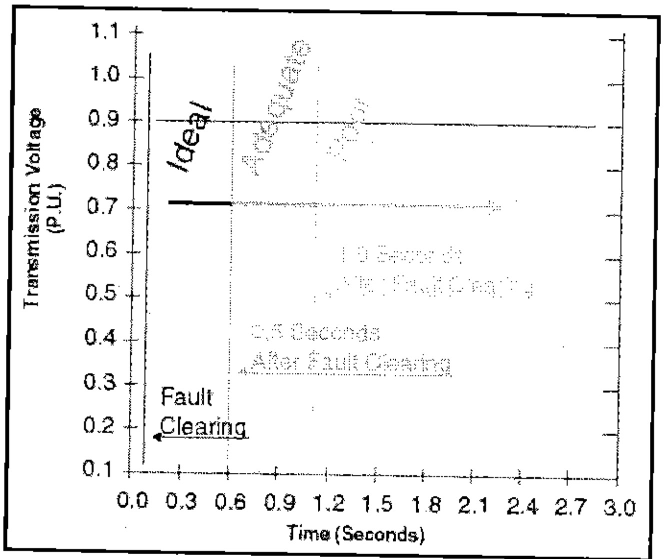


Figure 3 : Voltage Recovery Criteria [5]

The distribution network was obtained from Tenaga Nasional Berhad, Batu Pahat, Johor, Malaysia. The overall flow of this paper is summarized in the flow chart as shown in Fig. 4.

The PSCAD software was used to simulate the network where the single line diagram was converted to electrical network using mathematical formulas. For three phase loads, the active power was considered as load resistance and reactive power was considered as load inductance. The loads was calculated for each bus bar and the three phase voltage (V_{L-L}) from main supply sub-station (MES) is 11kV and apparent power (S) equal to 30MVA. The designed network using PSCAD is shown in Fig. 5 and Fig. 6 for the system without D-STATCOM and the system with D-STATCOM respectively.

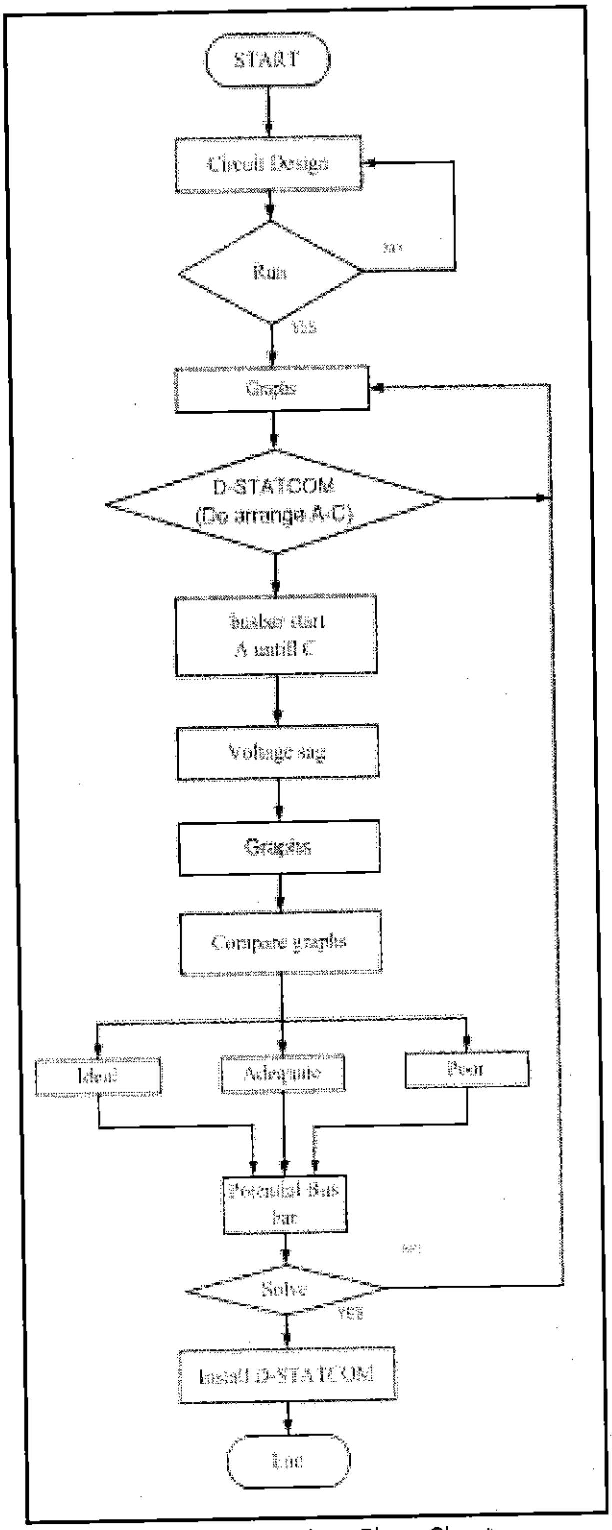


Figure 4 : Project Flow-Chart

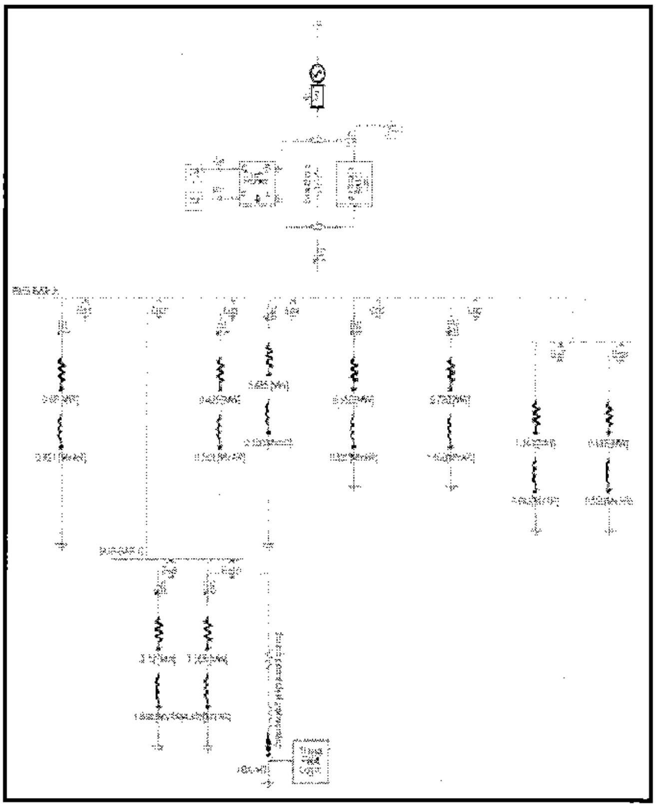


Figure 5 : Distribution System without D-STATCOM

The distribution network is divided into three group which are main bus bar A, main bus bar B and main bus bar C and the grouping of buses is shown in Table 1.

Table 1 : Grouping of main busbar

Group	No. of Bus
A	Busbar 1, Busbar 2, Busbar 3, Busbar 4 and Busbar 6
B	Busbar 7 and Busbar 8
C	Busbar 9 and Busbar 10

In this simulation, a fault time is set to 1 s and occurs from 0.5 s until 1.5 s. The fault component is connected in shunt to the study distribution system as shown in Fig. 5 and Fig. 6. The simulation is run in two conditions, which are, a network without D-STACOM and a network with D-STATCOM. The network without D-STATCOM is simulated to monitor the voltage at each main group bus bar and the voltage sag that been occurred. Modal analysis is used to identify the best location of D-STATCOM. The idea is to get the time of recovery based on voltage recovery criteria as shown in Fig. 3 where it is classified to ideal, adequate or poor. The ideal bus bar then will be chosen as the best location of D-STATCOM.

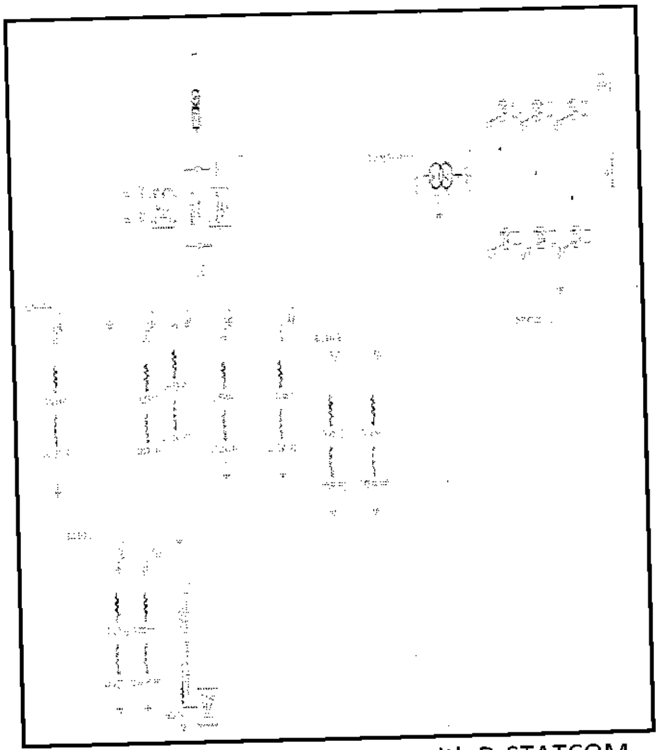


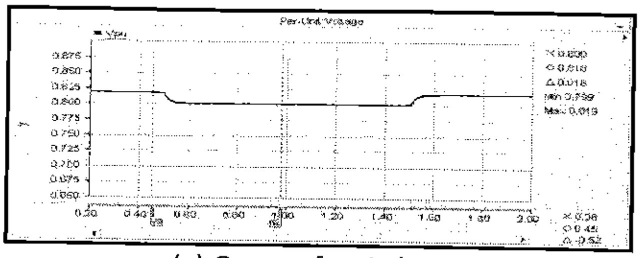
Figure 6 : Distribution System with D-STATCOM.

RESULTS AND ANALYSIS

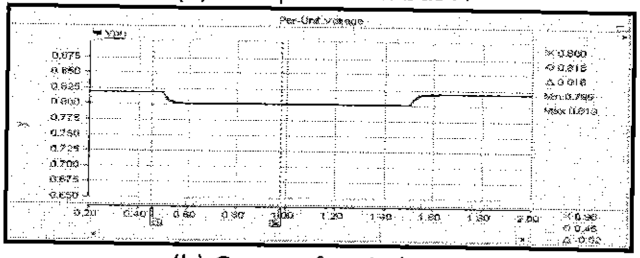
(A) Result of Simulation Network without D-STATCOM

The system was simulated for three seconds with three phase balance fault occurring at time 0.5 s for duration of 1.0 s. The results of simulation are shown in Fig. 7. For the system without D-STATCOM, the load voltage dropped from 0.818 p.u to 0.800 p.u at the group of main bus bar A as shown in Fig. 7(a).

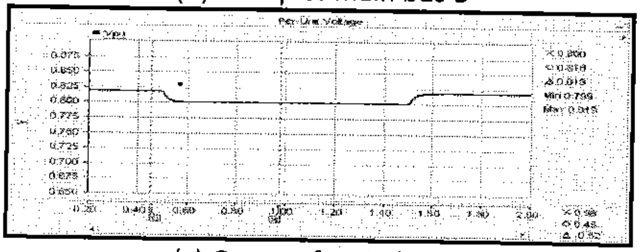
The voltage dropped starting from 0.5 s until 1.5 s because of faults time is set to start at 0.5 s for the duration of 1 s. After the fault time, the voltage will return constant at the normal condition. This short-term reduction in voltage is called voltage sag. In this simulation, the voltage sag is non-repetitive but in the real network, it can be happen.



(a) Group of main bus A



(b) Group of main bus B

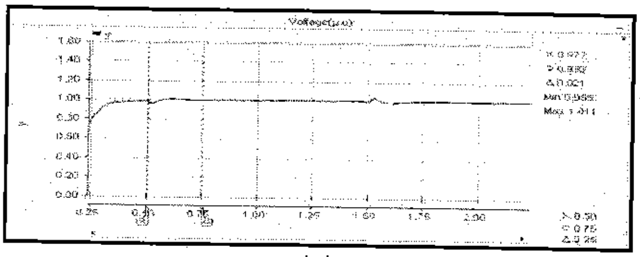


(c) Group of main bus C

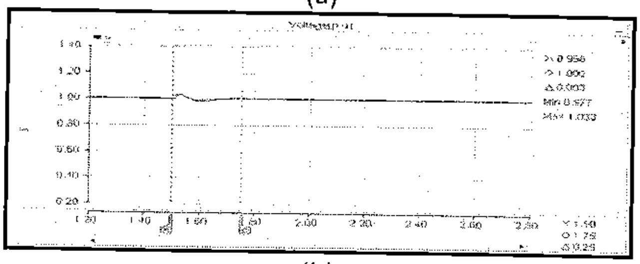
Figure 7 : Without D-STATCOM at (a) bus A, (b) bus B, (c) bus C

(B) D-STATCOM Allocated at Bus bar A, B and C for Voltage Sag Compensation.

The simulation results of the D-STATCOM at group bus bar A response in term of the load voltage in per unit are shown in Fig 8. For the system with the D-STATCOM connected in the system, the load voltage will increase from 0.800 p.u to 0.993 p.u as shown in Fig. 8(a) while Fig. 8(b) shows the load voltage takes 0.25 s to recover to the rated voltage.



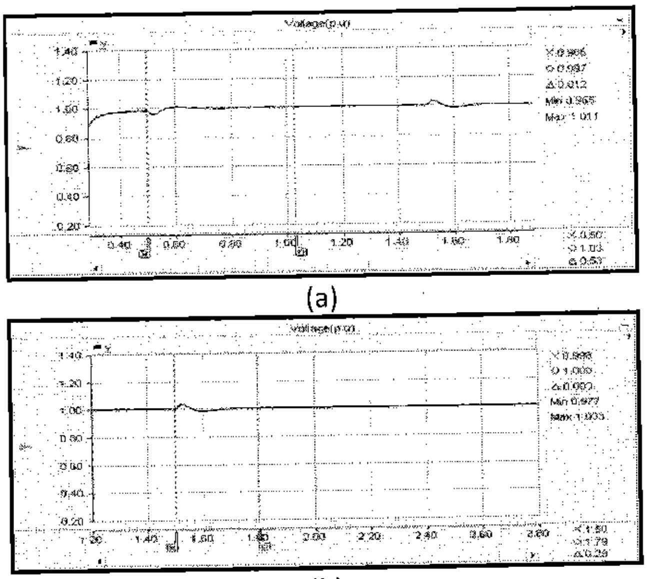
(a)



(b)

Figure 8 : Load voltage of group main Bus A, (a) With D-STATCOM. (b) Time of Recovery

The simulation results of the D-STATCOM at group bus bar B are shown in Fig. 9. For the system with the D-STATCOM connected in the system, the load voltage will increase from 0.800 p.u to 0.997 p.u as shown in Fig. 9(a). Fig. 9(b) shows the load voltage takes for 0.29 s to recover to rated voltage.

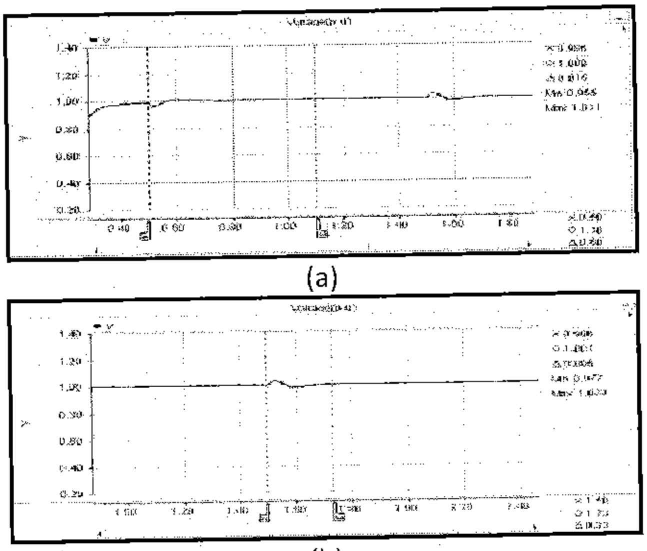


(a)

(b)

Figure 9 : Load voltage of group main Bus B , (a) With D-STATCOM. (b) Time of Recovery

This also happen at the main group bus bar C where it show that the system with the D-STATCOM connected, the load voltage improved from 0.800 p.u to 1.0 p.u as shown in Fig. 10(a), while the time recovery is about 0.23s as demonstrated in Fig. 10(b).



(a)

(b)

Figure 10 : Load voltage of main group Bus C , (a) With D-STATCOM. (b) Time of Recovery

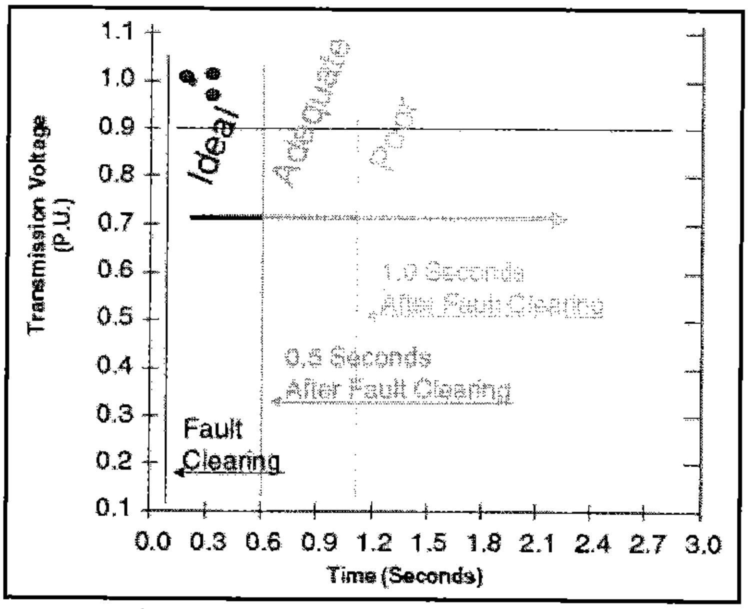


Figure 11 : Plot of voltage time recovery

From the results obtained, all the recovery time are plotted at the graph of voltage recovery time as shown in Fig. 11. The plotted graph demonstrates that all the clearing time is fall at the ideal condition means the D-STATCOM can be placed in any point of bus system. The results also presents a spike at the beginning and at the end of fault duration and these are caused by the process of charging and discharging of the capacitor in D-STATCOM circuit.

CONCLUSION

The simulation results obtained shows that, the D-STATCOM responded well in mitigating voltage sag caused by three-phase balance fault. The summarize data of voltage recoveries, time recoveries and classification of the network are depicted in Table 2.

Table 2

Location of D - STATCOM (Bus bar)	Voltage (V p.u) Without D-STA T COM	With D-STA TCOM	Time of recovery (s)	Classification
A	0.800	0.993	0.25	Ideal
B	0.800	0.997	0.29	Ideal
C	0.800	1.0	0.23	Ideal

SUMMARY OF NETWORK SIMULATION

Based on the recovery times, all locations are ideal to install D-STATCOM because voltages are recovered within 0.6s. Although the entire bus bar groups are ideal location, only the best location will be chosen. Therefore, the best solution for the power quality problem (voltage sag) in this distribution network is when D-STATCOM is located at main group bus bar C.

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