

A Comparative Study of the Influence of BESS and STATCOM on Post-Fault Voltage Recovery in Microgrid

Fabliha Ahmed, Silvia Tasnim, and Shourin Rahman Aura

Abstract — Reliable and efficient power flow in the electrical grid is crucial given network expansion and the incorporation of numerous renewable sources. Microgrids are becoming more and more important in the global energy sector due to its numerous benefits. The variable nature of distributed energy resources (DER) in microgrid makes large-scale DER integration potentially unstable for system voltage. Grid regulations place restrictions on the voltage control of DER unit, which raises the need for reactive power support. Proper placement of flexible AC transmission system (FACTS) under post-fault conditions may enable faster voltage recovery. In this work, battery energy storage system (BESS) and static synchronous compensator (STATCOM) have been considered for improving the post-fault voltage in DER integrated weakly grid-connected microgrid system. Two operation scenarios have been considered for analyzing the behavior of BESS and STATCOM individually at post-fault situation. According to the results of the simulation, BESS requires lesser rating than STATCOM for faster recovery of post-fault voltage of the system.

Keywords — BESS, DER, Microgrid, post-fault voltage recovery, STATCOM.

I. INTRODUCTION

The idea of Distributed Energy Resources (DER) and multi-source energy systems was mainly motivated by environmental issues due to centralized energy supply, the variability of fossil fuel costs, insufficient transmission capabilities, etc. Over the last few years, various DER associated with renewable and non-renewable energy resources and coordinated flexible AC transmission system (FACTS) devices serve optimally to a small distribution network with local electrical loads familiarly known as microgrid [1], [2]. A microgrid can be integrated with the main grid at the point of common coupling (PCC) which is coupled to the host power grid at the medium voltage (MV) and low voltage (LV) distribution networks. When the main grid fails, microgrids can use DER to power communities and vital infrastructure. In order to operate in both islanded and grid-connected modes, it may also connect to and detach from the utility at the PCC. By leveraging storage technology to locally balance generation and loads, microgrids are designed to manage variable generation.

DER integrated industrial microgrids show some benefits like voltage and reactive power control capabilities, reduced system loss, standby generation, power quality and reliability improvement etc. Moreover, microgrid enables flexible and effective distribution environment for resident electrical loads. These conveniences lead to the migration towards small scale autonomous distribution network [3], [4].

Despite the fact that microgrids have many benefits, there are certain technical challenges that need to be addressed to avoid cascading tripping DERs during any fault, specially three phase short circuit fault. Due to intermittent behavior of renewable DERs, voltage instability, power quality issues, voltage dips, voltage sags etc. the maintenance of rated voltage and rated frequency of microgrid lead to great difficulties [5]. Moreover, low voltage ride through (LVRT) performance in small-scale DER units is insufficient to handle frequency tripping, but large DER units offer better LVRT performance in response to grid control facility demands [6]. Insufficient reactive power support to the system during any abnormal scenario, can adversely affect stability of power grid and voltage collapse of the system may occur. Even after fault clearance, the rated voltage of the system remains at significantly lower value for several seconds known as fault-induced delayed voltage recovery (FIDVR). This FIDVR issue can cause subsequent black out of the microgrid if specially the system is islanded, or weakly grid connected industrial microgrid with lots of motor loads. So, post fault voltage recovery and voltage stability are hampered due to FIDVR issues and power electronics interfacing in DER [7].

In order to compensate these issues and establish a reliable power grid, installing FACTS devices such as static synchronous compensator (STATCOM), static Var compensator (SVC), energy storage system (ESS) etc. has gained significant attention in recent years. They can facilitate as reactive power management devices to support during dynamic contingencies, help reactive power planning to induce post fault voltage recovery and mitigate challenges related to voltage stability and control mechanism [8]. The type, placement and sizing of VAR sources play important role to improve post fault voltage recovery and overall power supply integrity. Insufficient sizing, wrong placement and inappropriate type selection of deployment can cause unwanted problems of voltage instability during any contingencies. Hence, appropriate sizing with proper location selection of VAR support is of utmost importance for voltage improvement as well as frequency recovery within allowable range after fault situations and sudden change in capacity [9].

Among various FACTS devices, BESS and STATCOM have shown reliable operation with fast reaction time of voltage recovery and sufficient reactive power supply.

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Different analysis has been performed to ensure suitable placement and size of BESS and STATCOM for improving post fault voltage recovery performance in case of voltage profile, frequency, power loss etc.

The analysis in [10] shows the proper integration of BESS at suitable location takes smaller current from storage unit and reduce the voltage level maintenance related problems at buses. The study in [11] exhibits that BESS integration at PCC of DER improves ramp support that leads to stability of post fault frequency fluctuation. This also signifies the post fault voltage recovery scenarios. By locating energy storage facilities in the best possible place to offer ancillary services, an alternating direction method of multiplier is suggested in [12]. The study in [13] and [14] clarifies that in a renewable integrated microgrid system, the sensitive buses can be determined by voltage sensitivity factor (VSF) for distributed placement of BESS. Such type of BESS placement has noteworthy impact on post fault voltage recovery along with frequency recovery than centralized placement. In [15], based on reactive power margin, a new placement methodology of BESS has been analyzed so that renewable integrated DER can avoid cascading tripping and achieve immunity against post fault contingencies. A business-oriented BESS location selection has been investigated in [16] based on some factors like renewable source integration, different economic strategies that not only minimize the costs but also improves voltage profiles of the system.

A new sensitivity index dV/dIR is employed to place STATCOM by replacing optimal capacitor in [17] to analyze the voltage recovery time for the generator and load buses and its effectiveness has been compared with the existing sensitivity index dV/dQ . The research in [18] represents that trajectory sensitivity index (TSI) based approach to improve FIDVR issues and post fault scenarios through optimal location selection for STATCOM. Due to high penetration of solar PV and induction motor loads the FIDVR related issues are minimized through a unique PV-STATCOM controller in [19]. The appropriate placement of this FACTS device with proposed control algorithm achieves maximum hosting capacity. For STATCOM placement, the authors provide a multi-objective optimization technique. To evaluate the static and dynamic voltage stability, three goals have been set for STATCOM placement in the study shown in [20].

The analysis in [21] shows the comparison between BESS and STATCOM about their performance in voltage recovery after cascading contingencies. The study emphasizes single and three phase faults. The comparative result signifies BESS placement for isolated microgrid having lower rating for grid compatible voltage recovery. This article in [22] describes a method for enhancing a BESS-based and STATCOM controlled based basic power system's transient stability limit related to voltage improvement. The investigations showed that the BESS is superior to a STATCOM of the same current rating.

The literature review above explains the performance capability of BESS and STATCOM in the improvement of post fault scenarios related to voltage profile, frequency, stability etc. Both the FACTS devices have shown greater impact on power system. In this study, the performance of

both the devices are analyzed under post fault scenarios to observe their capabilities to restore voltage after a severe three phase fault according to the grid rule. The comparison between their performance is shown through simulations to validate the best choice of suitable placement with proper rating of the device.

The paper is arranged as follows: Section II represents the modeling aspects of BESS and STATCOM in the industrial microgrid. Section III describes the IEEE suggested grid rules of a microgrid to accelerate voltage recovery after a fault in the system. Section IV proposes the methodology to find out appropriate placement, size, and selection of BESS or STATCOM. Section V contains the simulated result with analysis to signify the methodology. Section VI concludes the study showing proper comparison between BESS and STATCOM with future prospects.

II. MODELING OF BESS AND STATCOM IN MICROGRID

A. Battery Energy Storage System (BESS) Model

BESS are being utilized more frequently in FACTS applications as a means of enhancing the voltage level, frequency, system oscillation, transient stability, and the dependability of the power supply in islanded or weakly grid connected mode. BESS application has become significantly important to control real and reactive power flow. BESS can be placed at PCC of DER or any alternative location to support the system voltage at post fault scenario following severe fault. Proper placement of BESS can ensure not only the voltage level but also frequency regulation through quick ramping time [23]. Moreover, BESS can mitigate voltage regulation difficulties, minimization of voltage sag and related spikes [24].

The general BESS model application includes battery stacks, different FACTS controllers, pulse width modulation (PWM) based voltage source controller (VSC) etc. The energy storage device portion is interfaced with the three phase AC grid through series or shunt connected VSC and this part store or restore energy using electrochemical process. The PWM based VSC acts as rectifier or inverter that converts DC voltage of the storage part into PWM AC voltage and vice versa. BESS incorporated control scheme includes different controllers like PQ controller, charge controller etc. as shown in Fig. 1, which help to regulate BESS to supply active and reactive power as per system demand during any contingencies. The real and reactive power regulated by BESS are controlled and decoupled by d-axis current component (I_{dref}) and q-axis current component (I_{qref}) respectively. The voltage change at PCC terminal controls the reactive power regulation of BESS whereas the frequency deviation of the system regulates the active power flow of BESS [15], [25].

B. Static Synchronous Compensator (STATCOM)

STATCOM is a shunt FACTS device designed for controlling power flow and enhancing the transient stability of the grid to compensate reactive power. It can operate as capacitive device by generating reactive power at the PCC during lower system voltage. On the other hand, if system voltage remains high, the STATCOM can absorb reactive power at the PCC modeling as inductive device. Thus, this

VAR controlled device improves voltage profile in dynamic situation along with power factor of any DER integrated system [26].

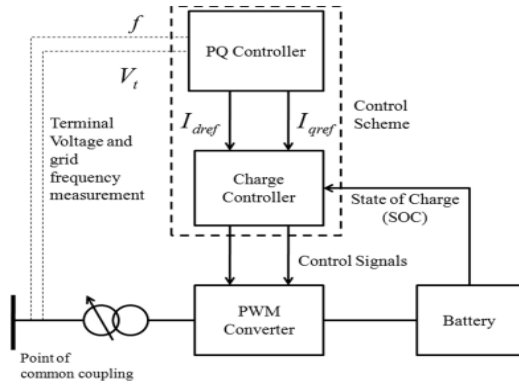


Fig. 1. BESS control system model (Block diagram) [24].

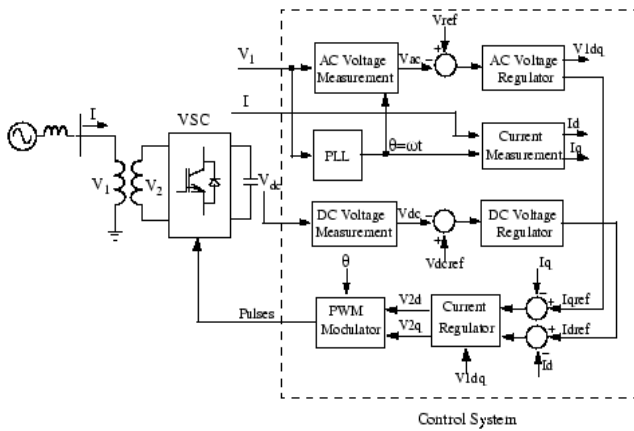


Fig. 2. STATCOM control system model (block diagram) [26].

STATCOM mainly consists of coupling transformer from grid side, voltage source converter (VSC) based PWM converter and DC capacitor. VSC generates three phase voltage and through a coupling transformer it feeds the grid system and its components are controlled against overvoltage across the DC capacitor. The capacitor acts as DC voltage source on the DC side of VSC. It operates in voltage control mode by keeping node voltage constant and reactive power control mode to maintain certain value of reactive power [27], [28].

Fig. 2 shows the single line diagram of the simplified block diagram of STATCOM control system. The positive-sequence component of the three-phase primary voltage, V_1 is synchronized by phase locked loop (PLL). The angle based output of the PLL calculates d and q components of three phase AC positive sequence voltages (V_d , V_q) and currents (I_d , I_q) along with DC voltage of capacitor, V_{dc} . In outer regulation loop, AC voltage regulator provides I_{qref} as reference reactive current to maintain specific bus voltage by controlling reactive power flow and DC voltage regulator supplies I_{dref} as reference active current to regulate constant capacitor voltage by controlling active power flow. The inner current regulator controls the magnitude and phase of PWM converter voltage (V_{2d} and V_{2q}) from I_{dref} and I_{qref} in voltage control mode to assist required reactive power by the STATCOM model. It is associated with a feed-forward-type regulator to predict V_{2d} and V_{2q} from V_{1d} and V_{1q} with the help of Leakage reactance (X_L) of the coupling transformer [26], [27].

III. GRID RULES ASSOCIATED TO MICROGRID OPERATION

In grid-connected mode, a microgrid is less susceptible to cascading situations of DER tripping as during fault the generation and load balance of the system maintained by the grid reserve capacity. But in weakly grid-connected or in island mode, the total connected load is almost equal to the generation capacity. Therefore, even minor, rapid changes have the potential to cause huge transients, necessitating DERs to have a relatively faster dynamic reaction in order to endure the disturbance [29]. To maintain this situation properly, the guidelines for connecting DER to electric networks are outlined in IEEE Standard 1547-2018 showing the minimum voltage recovery time and fault clearing time. According to the statement of the standard a DER must stop energizing after 0.16 s of clearing time if its point of common coupling (PCC) voltage is greater than 1.20 p.u. or lower than 0.45 p.u. Between 0.88 p.u. and 1.10 p.u. is the range of the usual operating voltage. The post fault voltages of DER at PCC must return to 0.88 p.u. of the voltage before fault within 2 s to 21 s depending on system operator requirement. The lowest allowable time 2 s need to be maintained to avoid cascading contingencies of DER tripping that can cause severe system failure.

TABLE I: VOLTAGE RECOVERY RESPONSES OF DER

Default values		Allowable range	
Voltage (p.u.)	Clearance Time (s)	Voltage (p.u.)	Clearance Time (s)
1.20	0.16	Fixed at 1.20	Fixed at 0.16
1.10	2.0	1.10-1.20	1.0-13.0
0.70	2.0	0.0-0.88	2.0-21.0
0.45	0.16	0.0-0.50	0.16-2.0

Table I outlines the allowable voltage recovery range in voltage p.u. and recovery time DER setting [30].

IV. PROPOSED METHODOLOGY

Finding proper placement of BESS or STATCOM and its appropriate size requires evaluation of the system where it needs to be placed. The following locations have been considered for the placements of BESS and STATCOM to analyze the voltage response of the system [31].

A. Point of Common Coupling of DERs

STATCOM or BESS connected at PCC of a system can usually maintain the voltage of the whole system properly in a microgrid. These are the usual placements of FACTS devices.

B. Most Sensitive Bus

The most sensitive bus of a system means that bus has the lowest reactive power rating and highest voltage sensitivity index. It is the weakest bus as small fluctuations in the total loading can impact the magnitude of the voltage at that bus greatly. BESS placement at this bus is found useful in [13].

C. Bus with Largest Real Load

The bus with maximum real load can be considered for the location of BESS or STATCOM. It can be noted that this bus works well for fast frequency recovery following a fault [32]. Nonetheless, the effectiveness of voltage recovery for this bus has not been studied.

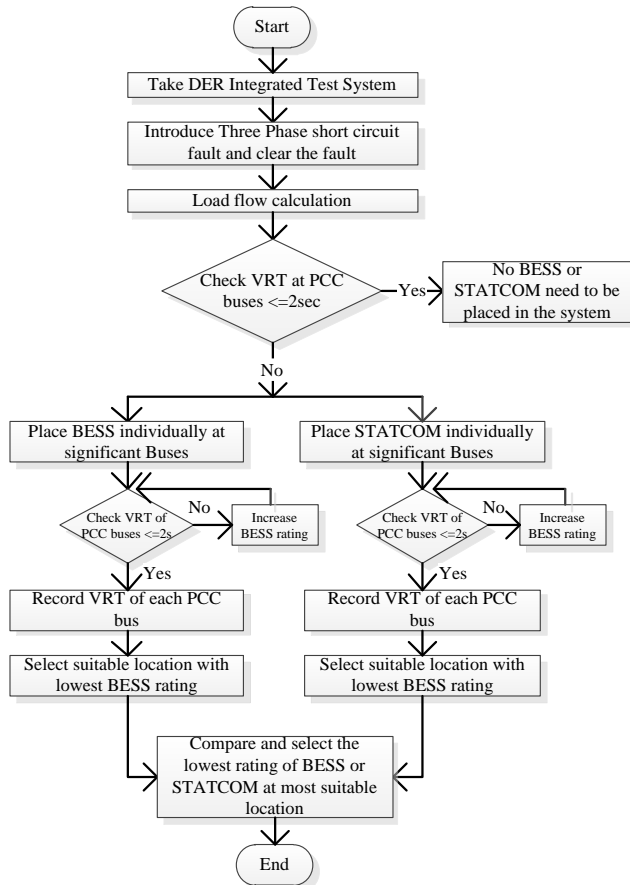


Fig. 3. Flowchart for proposed methodology.

The flowchart shown in Fig. 3 depicts the proposed methodology of this work. At first, a test system with DER integrated is considered where three phase fault is introduced. Load flow study is carried out on the system to see if the system voltage is able to recover after the fault clearing time according to the grid rule, otherwise BESS or STATCOM needs to be placed in that system.

For the placement of BESS at the particular locations individually, initially lower rating of BESS is considered to see whether the system voltage recovers within 2 s. If a BESS of that rating can successfully recover the system accordingly, then that size of BESS is preferable. Otherwise, the size needs to be increased and VRT needs to be checked again. The placement for which BESS has minimal rating is considered suitable.

A STATCOM of lower rating is placed at the designated locations one at a time to observe the voltage response of the system. Rating of the STATCOM is increased if the previous size fails to recover the voltage of the system. The location with lower rating of STATCOM which abides the grid rule is found appropriate.

After comparing all the results, the location for which the lowest rating of BESS or STATCOM is found, can be considered suitable for the placement of that device.

V. RESULTS AND ANALYSIS

The system under consideration for analysis is a test system of an industrial microgrid that is weakly connected to the main grid. It is a modified IEEE 43 bus test system as shown in Fig. 4.

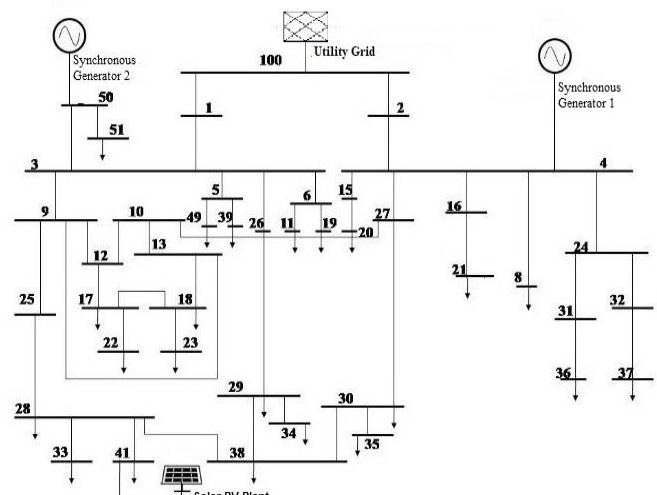


Fig. 4. A modified IEEE 43 bus microgrid system.

The system has two synchronous generators of 12 MVA each and one solar photo-voltaic plant of 3 MVA. Initially, total load of the system is 43.03 MVA. Location and rating of each DER sources are shown in Table II.

DER	Location	Rating
Synchronous Generator 1	Bus 4	12 MVA
Synchronous Generator 2	Bus 50	12 MVA
Solar PV Plant	Bus 41	3 MVA

In this weakly connected microgrid system, the initially selected locations according to section IV for the placement of BESS or STATCOM are bus 4, bus 50, bus 41, bus 37 and bus 8. Here, bus 4, bus 50 and bus 41 are PCC buses, bus 37 is the most sensitive bus and bus 8 has the largest real load.

A three-phase fault has been introduced at bus 3 which is near generator bus at 1 s and cleared at 1.2 s with 0.15 Ω fault impedance for all scenarios. Two operation scenarios have been considered to observe the behaviour of BESS and STATCOM in post-fault voltage recovery condition. BESS and STATCOM are placed individually at the selected buses and post-fault voltages at PCC buses (bus 4, bus 50 and bus 41) have been observed for all cases. All simulations are conducted using Digsilent Power Factory 15.1.

A. Operation Scenario 1: Initial Load Condition

1) Impact of BESS

Initially, a 0.5 MVA BESS is placed at one of the PCC buses (bus 4) in this scenario, but the system doesn't recover for this rating as shown in Fig. 5.

For the placement of BESS of 0.5 MVA at all other selected buses, similar voltage responses have been found at the PCC buses.

When BESS of 1 MVA is placed at bus 4, then voltage recovered at bus 4 with voltage recovery time 1 s as shown in Fig. 6(a). For this location of BESS, voltage also recovered successfully at other PCC buses and similar voltage recovery time has been found. BESS of 1 MVA is placed individually at other selected locations, and voltage is recovered within 2 s at bus 4 for these placements as shown in Fig. 6(b-e). Identical voltage responses been found at bus 50 and bus 41, therefore only the voltage response of bus 4 has been shown.

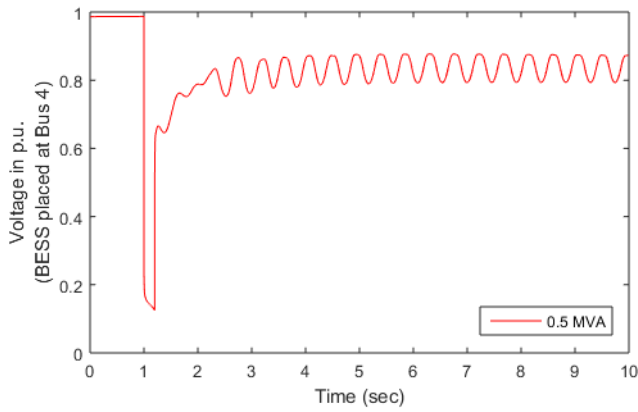
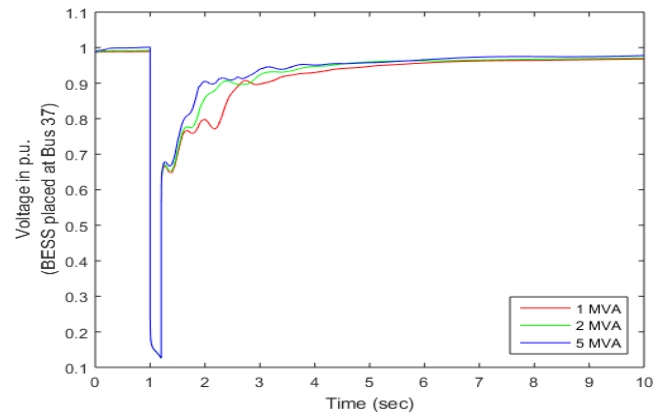
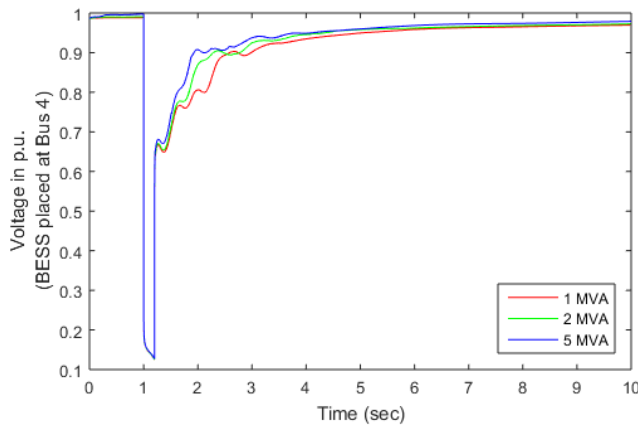


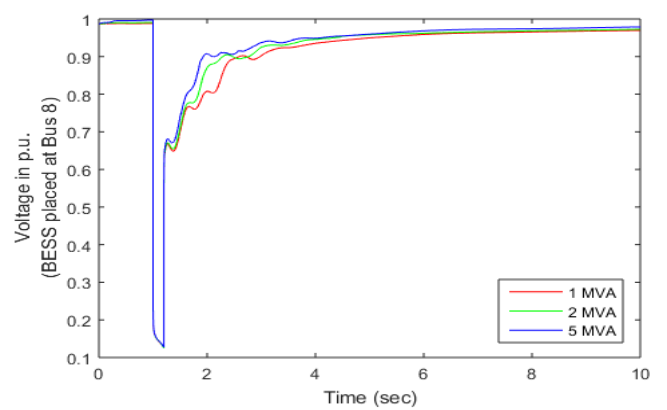
Fig. 5. Response of post-fault voltage at bus 4 with BESS of 0.5 MVA.



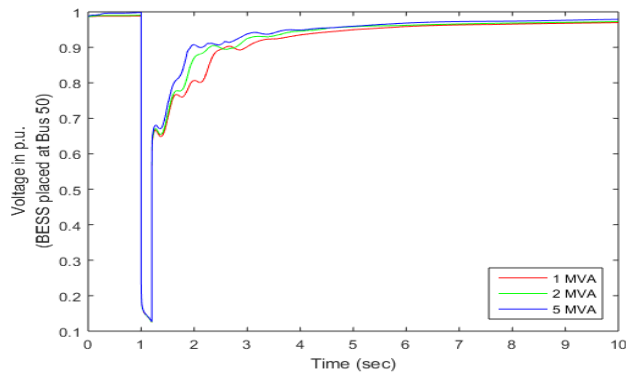
(d) Response of post-fault voltage at bus 4 when BESS is placed at bus 37.



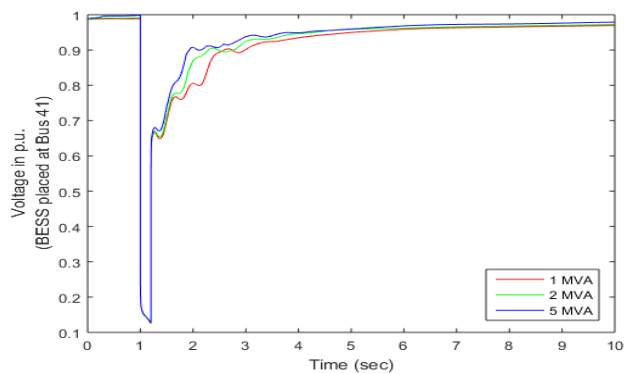
(a) Response of post-fault voltage at bus 4 when BESS is placed at bus 4.



(e) Response of post-fault voltage at bus 4 when BESS is placed at bus 8.
Fig. 6. Responses of post-fault voltage at selected locations with BESS of 1 MVA, 2 MVA and 5 MVA.



(b) Response of post-fault voltage at bus 4 when BESS is placed at bus 50.



(c) Response of post-fault voltage at bus 4 when BESS is placed at bus 41.

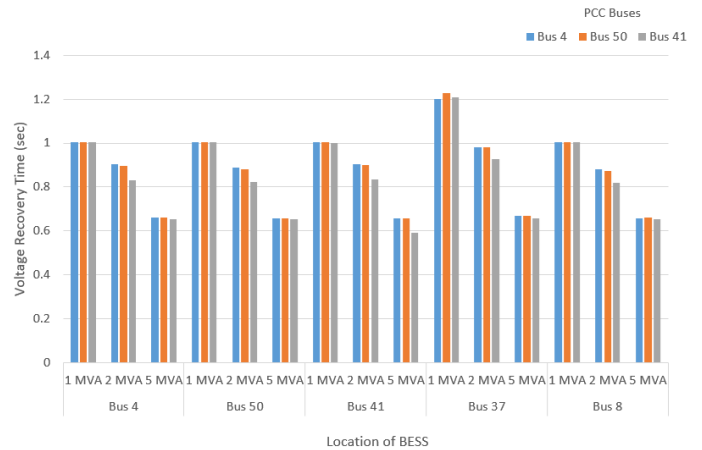


Fig. 7. Voltage recovery time of PCC buses with BESS of 1 MVA, 2 MVA and 5 MVA placed individually at selected locations.

When the rating of BESS increases, VRT decreases. For 1 MVA of BESS, VRT is higher for the placement at bus 37 than all other placements as shown in Fig. 7. Though for 5 MVA of BESS, VRT is found around 0.62 s, but lower rating of BESS is desirable which can obey grid compatibility rule. Hence, BESS of 1 MVA will be preferable as it can support VRT for all the locations.

2) Impact of STATCOM

STATCOM of 1 MVA is placed at bus 4 initially. The post-fault voltage response is shown in Fig. 8. The system voltage doesn't recover when the rating of STATCOM is 1 MVA or less.

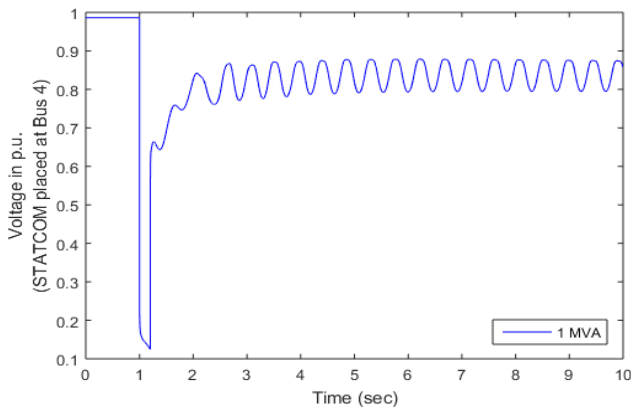


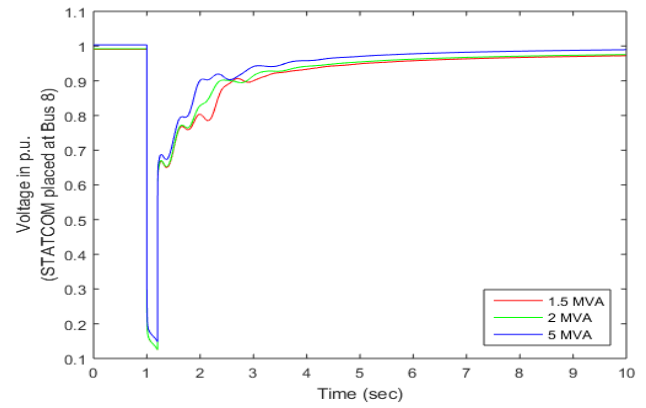
Fig. 8. Response of post-fault voltage at bus 4 with STATCOM of 1 MVA.

Voltage is recovered within 2 s for the placement of 1.5 MVA STATCOM individually at bus 4, bus 50 and bus 8 as shown in Fig. 9(a-c). Voltage responses are also similar at other PCC buses, therefore only the response of bus 4 is shown.

It is found from Fig. 10 that for the placement at bus 37, the voltage of the system only recovers when STATCOM rating is 4 MVA or higher.

When the STATCOM is placed at bus 41, minimum 5 MVA rating is required for the system to recover as shown in Fig. 11.

Fig. 12 shows that VRT becomes lower as the rating of STATCOM increases. For 1.5 MVA of STATCOM, comparatively lesser VRT (1.35 s) is found for the placement at bus 50. As lower rating of STATCOM abiding grid compatibility rule is preferred, therefore 1.5 MVA STATCOM is suitable in this scenario.



(c) Response of post-fault voltage at bus 4 when STATCOM is placed at bus 8.

Fig. 9. Responses of post-fault voltage at selected locations with STATCOM of 1.5 MVA, 2 MVA and 5 MVA.

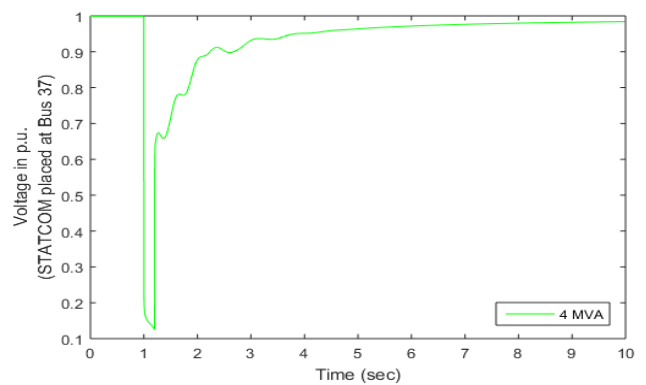
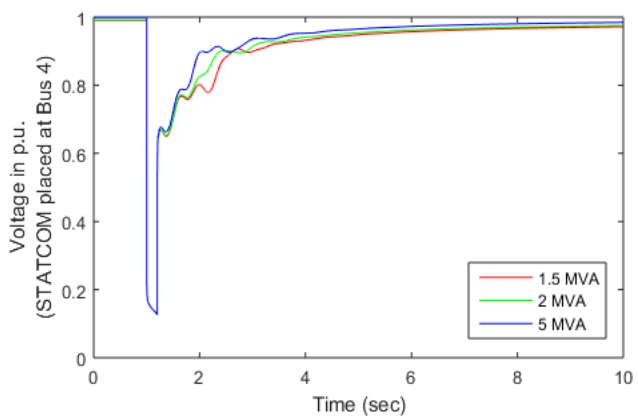


Fig. 10. Response of post-fault voltage at bus 4 when STATCOM is placed at bus 37.



(a) Response of post-fault voltage at bus 4 when STATCOM is placed at bus 4.

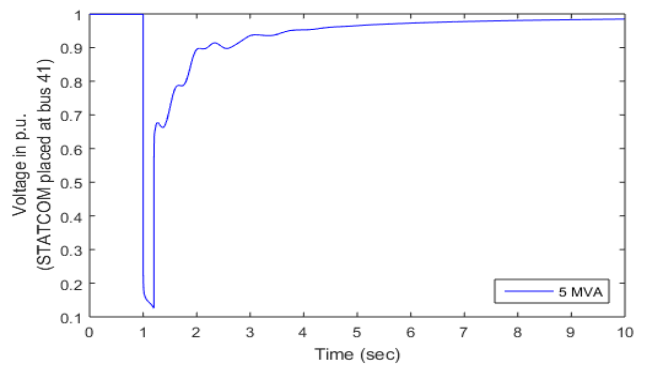
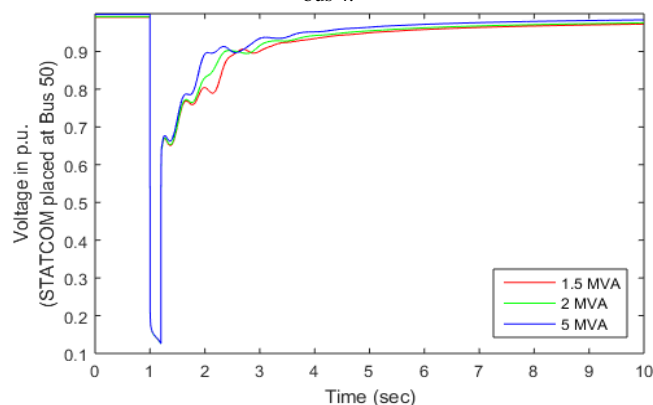


Fig. 11. Response of post-fault voltage at bus 4 when STATCOM is placed at bus 37.



(b) Response of post-fault voltage at bus 4 when STATCOM is placed at bus 50.

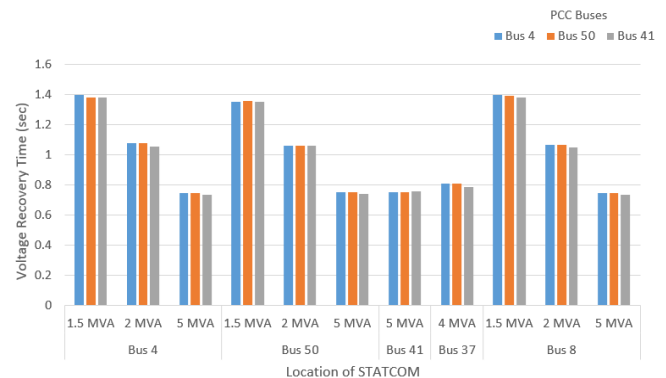


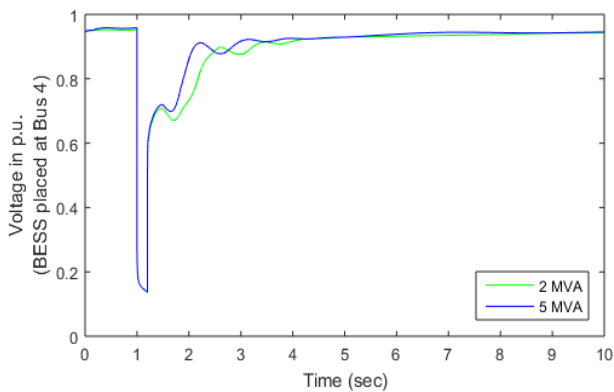
Fig. 12. Voltage recover time of PCC buses at selected locations with STATCOM of 1.5 MVA, 2 MVA and 5 MVA.

In operation scenario 1, it can be observed that BESS performs better than STATCOM with lower rating (1 MVA). VRT for 1.5 MVA STATCOM is around 1.4 s and 1 MVA BESS is around 1 s. In addition, 1 MVA BESS can recover the system successfully for all the selected locations. However, for the placement of BESS at bus 37, the VRT becomes higher than the four other locations. Therefore, a BESS of 1 MVA is suitable in post-fault condition for the placement at any PCC buses (bus 4, bus 50 and bus 41) or at the bus with maximum real load (bus 8) in this scenario.

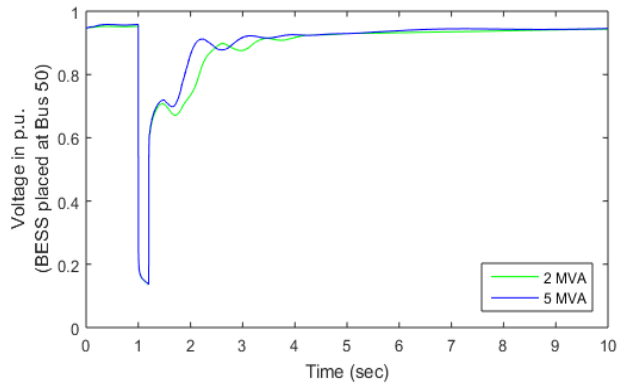
B. Operation Scenario II: 43.2% Increased Load Condition

1) Impact of BESS

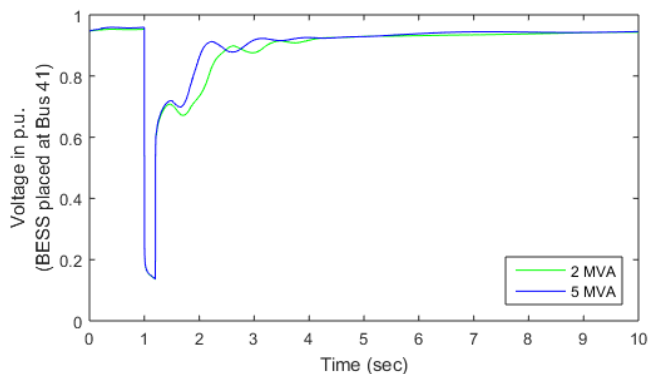
In this scenario, when BESS rating is less than 2 MVA, the generator pole slips and system voltage after the fault doesn't recover. Voltage responses at bus 4 for BESS of 2 MVA and higher at the selected five locations are shown in Fig. 13 (a-e).



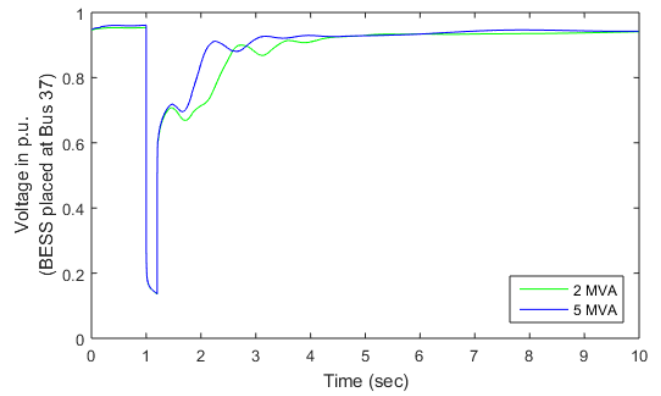
(a) Response of post-fault voltage at bus 4 when BESS is placed at bus 4.



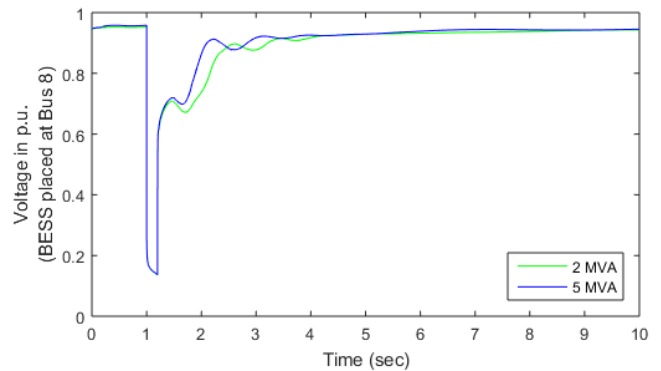
(b) Response of post-fault voltage at bus 4 when BESS is placed at bus 50.



(c) Response of post-fault voltage at bus 4 when BESS is placed at bus 41.



(d) Response of post-fault voltage at bus 4 when BESS is placed at bus 37.



(e) Response of post-fault voltage at bus 4 when BESS is placed at bus 8.
Fig. 13. Responses of post-fault voltage at selected locations with BESS of 2 MVA and 5 MVA.

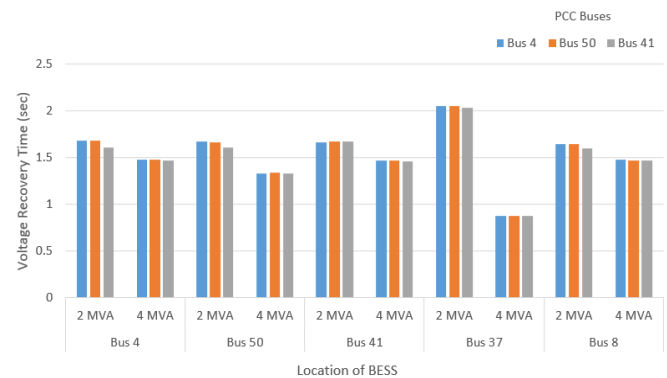
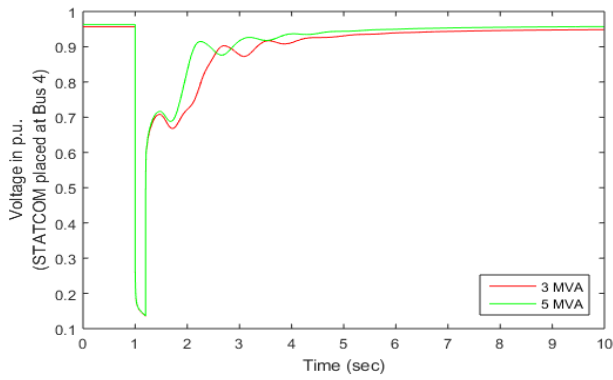


Fig. 14. Voltage recovery time of PCC buses at selected locations with BESS of 2 MVA and 4 MVA

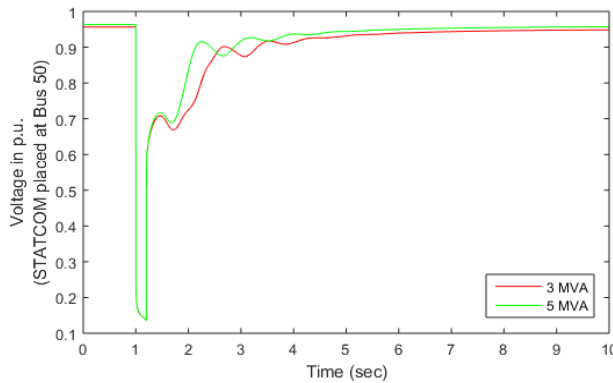
Voltage recovery time after the fault for the placement of different rating of BESS individually is shown through the bar diagram in Fig. 14. For all the placements, a BESS of 2 MVA can recover the system voltage suitably except for the location at the most sensitive bus (bus 37) where VRT is 2.1 s which doesn't follow the grid rule. When the rating of BESS is increased, then the VRT becomes less than 2 s for that location. The grid rule is satisfied for all other placement of 2 MVA BESS.

2) Impact of STATCOM

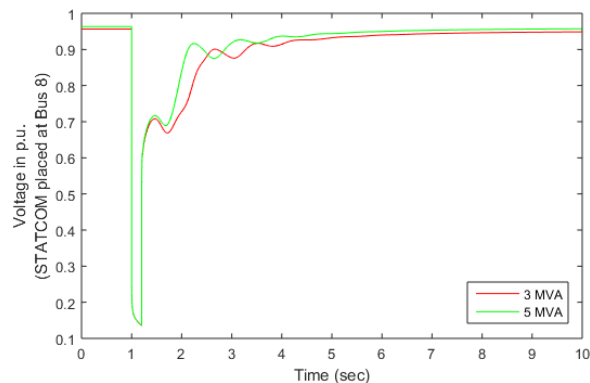
The system voltage is unable to recover for a STATCOM rating less than 3 MVA in this scenario of increased load condition.



(a) Response of post-fault voltage at bus 4 when STATCOM is placed at bus 4.



(b) Response of post-fault voltage at bus 4 when STATCOM is placed at bus 50.



(c) Response of post-fault voltage at bus 4 when STATCOM is placed at bus 8.

Fig.15. Responses of post-fault voltage at bus 4, bus 50 and bus 8 with STATCOM of 3 MVA and 5 MVA.

When a 3 MVA STATCOM is placed individually at bus 4, bus 50 and bus 8, VRT after fault is found within limit as shown in Fig. 15 (a-c). Voltage responses only for bus 4 is shown as identical responses are found for other PCC locations.

STATCOM of 5 MVA, placed at bus 37, cannot recover the system voltage as shown in Fig. 16. For the location of bus 41, the similar rating STATCOM also fails to recover the system voltage.

In this increased load condition, a 3 MVA STATCOM can recover the voltage at post-fault condition for the placement at bus 4, bus 50 and bus 8 only as shown in Fig. 17. With the increase in rating of STATCOM at these locations, VRT also decreases.

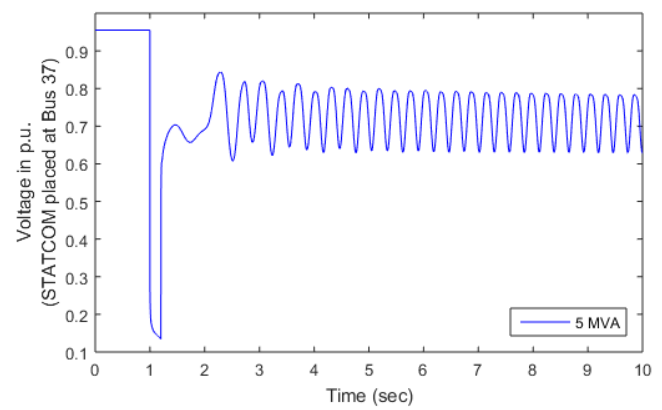


Fig. 16. Response of post-fault voltage at bus 4 when STATCOM is placed at bus 37.

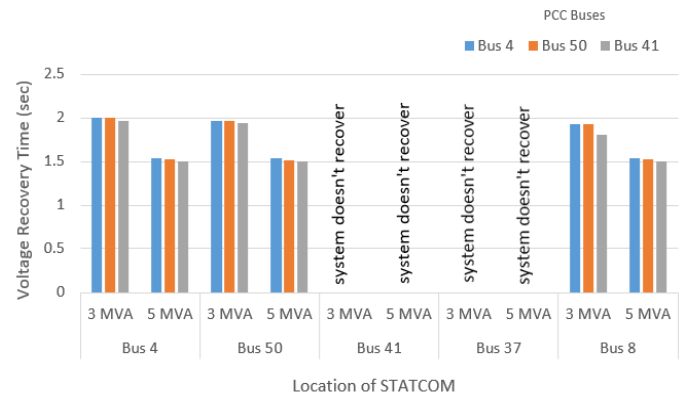


Fig.17. Voltage recovery time of PCC buses with STATCOM of 3 MVA and 5 MVA placed individually at selected locations.

TABLE III: REQUIRED RATING OF BESS AND STATCOM FOR POST-FAULT VOLTAGE RECOVERY AT PCC BUSES

Location	Operation Scenario I		Operation Scenario II	
	BESS	STATCOM	BESS	STATCOM
Bus 4	Minimum 1 MVA required	Minimum 1.5 MVA required	Minimum 2 MVA required	Minimum 3 MVA required
Bus 50	Minimum 1 MVA required	Minimum 1.5 MVA required	Minimum 2 MVA required	Minimum 3 MVA required
Bus 41	Minimum 1 MVA required	Minimum 5 MVA required	Minimum 2 MVA required	Voltage doesn't recover for 3 MVA or 5 MVA
Bus 37	Minimum 1 MVA required	Minimum 4 MVA required	Minimum 3 MVA required	Voltage doesn't recover for 3 MVA or 5 MVA
Bus 8	Minimum 1 MVA required	Minimum 1.5 MVA required	Minimum 2 MVA required	Minimum 3 MVA required

Table III summarizes the two operation scenarios. From both operation scenarios, it is clear that BESS performs better than STATCOM with lower rating in this test system. A BESS of 2 MVA placed individually at any of the PCC locations (bus 4, bus 50 and bus 41) or the bus with maximum real load (bus 8) can satisfy the IEEE std. grid rule for both case studies.

VI. CONCLUSION

In order to sustain supply-demand balance in a weakly grid-connected microgrids, BESS and STATCOM are both essential. After any form of fault, maintaining voltage

stability in the power system is a serious concern. Proper placement of BESS or STATCOM can influence the system voltage to recover quickly. In this study, five locations have been considered for the placement of BESS or STATCOM. It is observed from the results that, BESS with a lower rating in this test system can clearly performs better than STATCOM for both scenarios. Additionally, PCC buses and the bus carrying the heaviest load may be ideal candidates for BESS deployment. In future work, proper placement, and sizing of these devices for different systems can be determined by using optimization technique.

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