Placement of Battery Energy Storage System in Distribution System for improving Power Quality and Reliability

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Abstract: The power system has been witnessing significant changes over the past few decades. In the traditional power system, the role of electricity storage was limited. However, the situation has been changing with the increased integration of renewable energy sources and rapid development of new energy storage technologies. Energy storage technologies have a great potential to provide benefits to the power system, such as supply and demand flexibility, better efficiencies in the system operation, electricity price arbitrage, etc. Battery energy storage system (BESS), as one of the most promising energy storage technologies, has drawn considerable attention in both research and industry. BESS can provide a variety of services to the power system, such as peak shaving, load following, improving power quality & reliability and frequency regulation. Given the high capital cost of BESS, it is important to develop effective methods to find the placement of BESS in the distribution system. In practice, the placement and sizing problems should be considered together, because the best placement may vary with different sizes of the BESS. This paper tries to contribute in this field for placement of BESS in distribution networks. Also, a practical approach is proposed to deal with the placement problem when the BESS could be installed at multiple candidate locations. Moreover, a case study using a IEEE 16-bus test system is conducted to validate the proposed method.

Keywords: BESS, Reliability Indices, SAIFI, SAIDI.

1. Introduction

On October 12, 2020, a failure befell with inside the state-run energy transmission company, Mumbai grid, main to a disruption with inside the energy deliver throughout Mumbai. The grid failure prompted a huge blackout in numerous elements of the city, affecting residential, commercial, and Industrial areas. The energy outage caused disruptions in critical offerings, inclusive of transportation, hospitals, and offices. Train offerings had been affected, main to sizable inconvenience for commuters. Efforts had been right away initiated to repair energy, and various utilities labored to discover and rectify the issue. Restoration of energy delivery becomes executed in a phased manner, prioritizing essential offerings which include hospitals. It took numerous hours to repair energy absolutely to all affected areas, and normalcy become progressively regained. The grid failure highlighted the want for strong infrastructure and dependable structures to save you from such incidents in the future. It additionally sparked discussions on enhancing the resilience of the energy grid and imposing measures to reduce the effect of comparable failures. In Mumbai Distribution System, there are numerous essential purchasers which might be non-stop method industries, and which desires electric energy 24x7. For such consumers power quality and reliability is utmost precedence as moderate deviation in both of these will have an effect on the entire process and may purpose a big economic loss. These interruptions additionally have an effect on the reliability indices. One of the main challenges in operating and planning electric power distribution networks is to maintain the frequency of the power supply which is closely related to power quality. In order to match the supply and demand, the power generation has to be adjusted in real-time and the frequency quality of the power system has to be kept within a certain pre-specified limit. The main traditional method of achieving this is by using frequency control provided by large generators. These generators are expensive to run, slow to respond to rapid deviations in demand, and subject to electrical and mechanical losses. To alleviate these problems, battery energy storage systems (BESS) can be used in accelerating and smoothing the frequency control response. Unlike an unbalanced output of large generators, BESS can provide both active power and reactive power to change the voltage magnitude in the network by using control circuits. As a result, it has the capability to respond to the power imbalances within a few milliseconds and has the ability to support and stabilize the distribution system by providing the output power so that the system's frequency can be maintained within a very tight band. This paper focuses on the placement of Battery Energy Storage Systems (BESS) in distribution networks.

2. Issues Related to Electrical Distribution System

2.1 Power Quality

IEEE Standard 1100-2005 [1] defines power quality as “the concept of powering and grounding sensitive electronic equipment in a manner that is suitable to the operation of that equipment.

The power supply quality has become an essential deliverable of distribution utilities for their consumers and equipment manufacturers. The power is due to the use of non- linear power electronic loads. Power quality (PQ) is the amalgamation of current quality and voltage quality. Any deviation in sinusoidal voltage and current wave forms is defined as Power Quality (PQ) disturbance. It includes the voltage flicker, harmonics, voltage sag and swell, three phase imbalance, switching transients and interruptions. IEEE uses specific terminology to define power quality problems. These are the following Over voltages, Under voltages, Sags, Swells, Transients, Noise, Harmonics, and Grounding.

2.2 Reliability of Power Supply

The reliability of an electrical supply system considers its accomplishment to maintain service continuity. In this scenario the service is to make electricity supply continuously available for the end-user customers of the supply system or distribution system. When supply system fails to deliver continuous power, there are consumers that experiences service interruptions, which means that these consumers are de-energized. Reliability of electricity supply is primarily concerned with duration and frequency of such service interruptions. Thus, one can say that reliability of supply is a customer-oriented quantity that does not consider the origin of the causes of interruptions. The reliability of supply thus depends on the performance of generation, transmission, and distribution. Availability is often used as one measure of reliability.

3. Case Study

The solution is tested on IEEE 16 bus system. The schematic diagram is shown in Figure 1 The test system is modelled in CYMEDIST software for analysis.

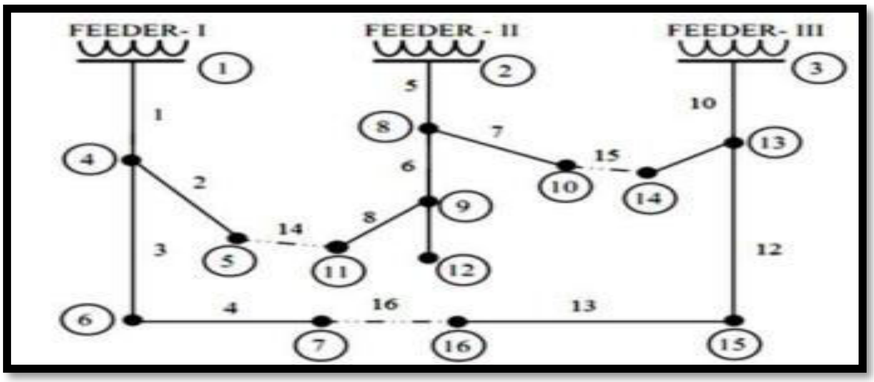

Figure 1. IEEE 16 Bus System

Table 1. IEEE 16 Bus System Parameters

Line No	From Bus i	To Bus j	R (Ω) P.U	X (Ω) P.U	Receiving Bus j P	Receiving Bus j Q
1	1	4	0.075	0.10	2.0	1.6
2	4	6	0.09	0.18	2.0	-0.4
3	4	5	0.08	0.11	3.0	0.4
4	5	11	0.04	0.04	-	-
5	6	7	0.04	0.04	1.5	1.2
6	9	11	0.11	0.11	0.6	-0.5
7	2	8	0.11	0.11	4.0	2.7

8	8	9	0.8	0.11	5.0	1.8
9	8	10	0.11	0.11	1.0	0.9
10	9	12	0.8	0.11	4.5	-1.7
11	7	16	0.12	0.12	-	-
12	15	16	0.4	0.4	2.1	-0.8
13	10	14	0.04	0.04	-	-
14	13	14	0.9	0.12	1.0	-1.1
15	3	13	0.11	0.11	1.0	0.9
16	13	15	0.8	0.11	1.0	0.9

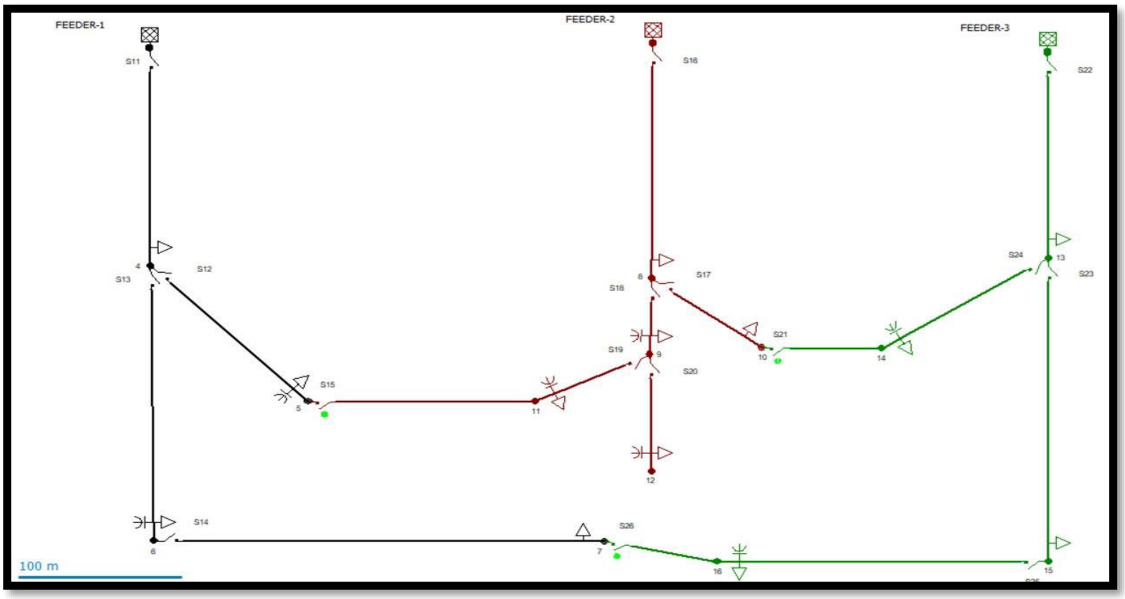

Figure 2. IEEE 16 BUS System as modelled in CYME software

Battery energy storage system is applied to each feeder strategic location.
Figure 3. Shows the IEEE 16 bus system with BESS application.

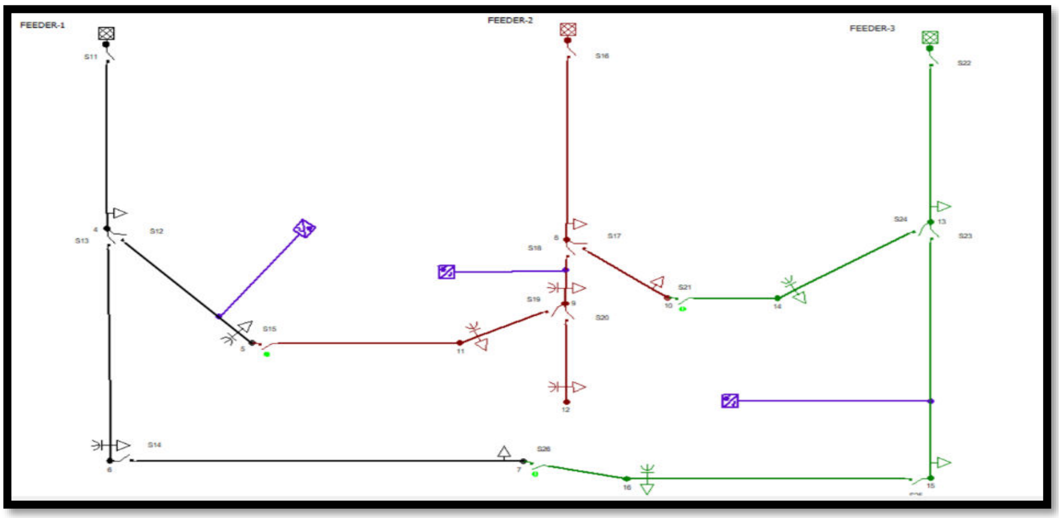

Figure 3. IEEE 16 BUS System with BESS as modelled in CYME software

BESS is applied to one of the feeder in Mumbai distribution system to check its reliability indices and power quality.

4. Results

When BESS is not in service, the values of reliability indices are mentioned in section A of Table -1. When BESS is connected to the distribution system, after failure of power supply, entire load is fed through the BESS, hence the reliability indices are zero since there is no interruption to any of the customer.

Table 2. Reliability Indices of Distribution System

	Without BESS (A)			**With BESS (B)**		
FEEDER	SAIFI	SAIDI	CAIDI	SAIFI	SAIDI	CAIDI
FEEDER 1	8.750	17.273	1.974	0	0	0
FEEDER 2	8.750	18.747	2.143	0	0	0
FEEDER 3	8.750	19.115	2.185	0	0	0

When the capacity of the battery is such that it is feeding partial load, the reliability indices are mentioned in Section B of table 3.

Table 3. Reliability Indices of Distribution System with partial BESS Capacity

	Without BESS (A)			**BESS with partial capacity (B)**		
FEEDER	SAIFI	SAIDI	CAIDI	SAIFI	SAIDI	CAIDI
FEEDER 1	8.750	17.273	1.974	6.546	16.369	2.501
FEEDER 2	8.750	18.747	2.143	6.546	16.205	2.476
FEEDER 3	8.750	19.115	2.185	6.546	16.573	2.532

* SAIFI is indicated in interruptions /customer -year. SAIDI is indicated in Hours /customer -year and CAIDI is indicated in Hours /customer -Interruptions

It is concluded that with the installation of battery energy storage system integrated with distribution system, the reliability indices are improved.

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Figure 4 a,b and c shows, the power flow curves as captured in cyme with different load curves after installing BESS on the feeder. It is clearly showing that BESS discharges when there is drop in supply to bridge the gap.

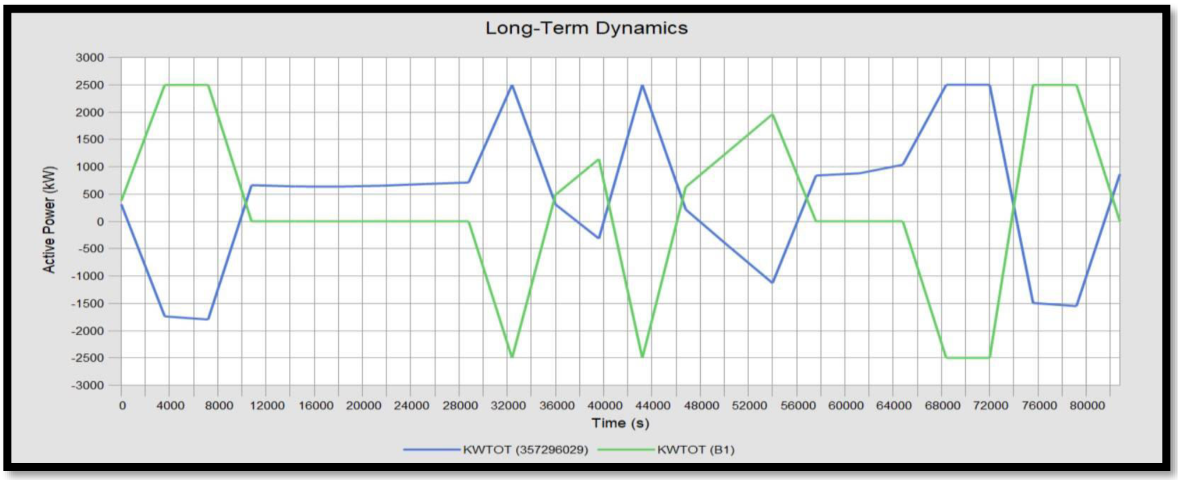

Figure 4a. Power Flow curve of Load No. 357296029 with BESS

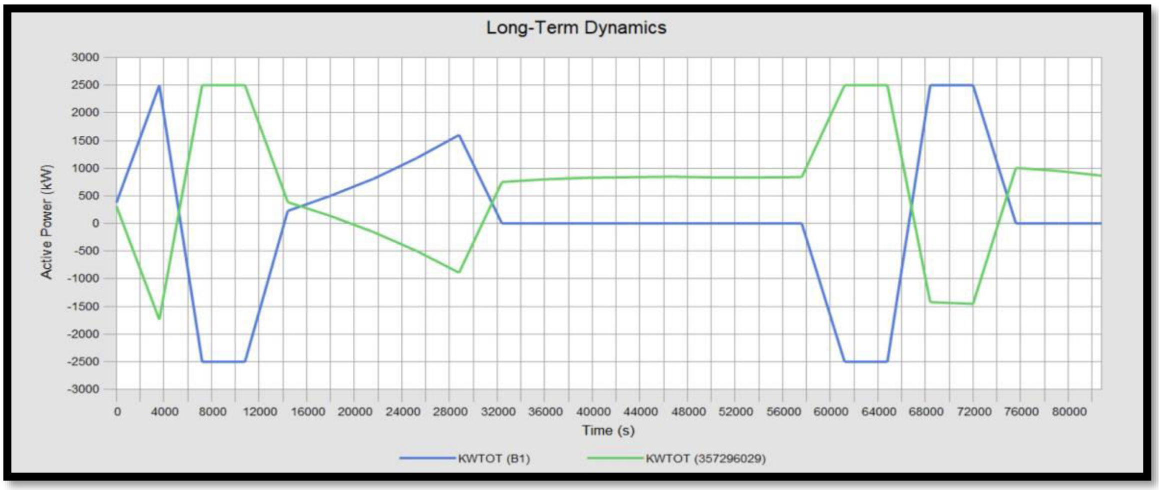

Figure 4b. Power Flow curve of Load No. 357296029 with BESS

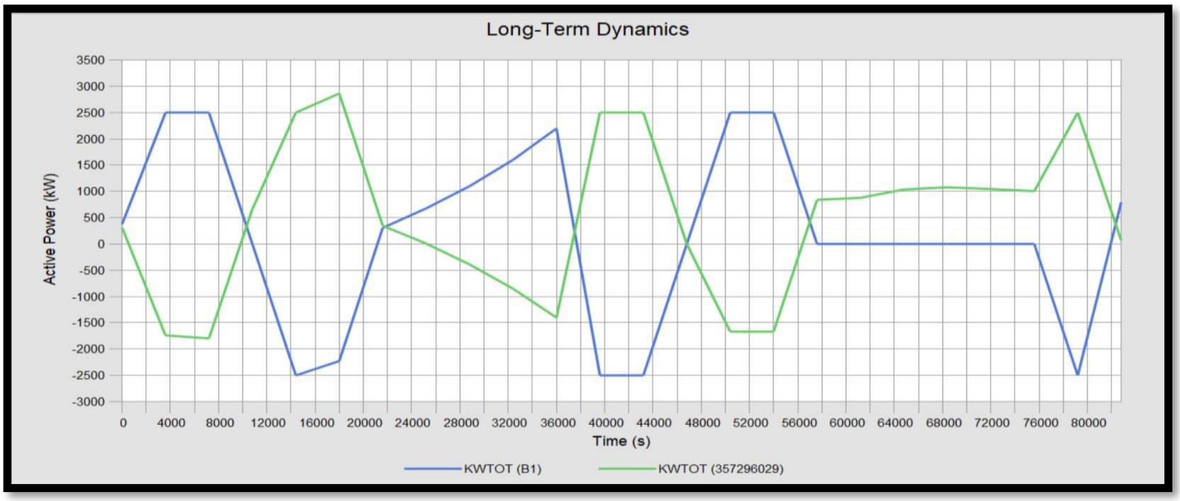

Figure 4c. Power Flow curve of Load No. 357296029 with BESS

6. Discussion and conclusion

It is concluded that the strategic deployment of BESS results in enhancements in the reliability of distribution networks. By imparting a fast reaction to disturbances and making sure a non-stop strength supply, BESS correctly reduces the frequency and period of the interruptions. The reliability indices of the system such as System Average Interruption Duration Index (SAIDI) System Average Interruption Frequency Index (SAIFI) were reduced with help of BESS. The BESS delivers the power when system voltage is absent and when system voltage is restored the BESS gets cut off as seen in the figure 4. The integration of battery energy storage systems (BESS) offers significant improvements in the reliability and power quality. To guarantee greater dependability, it is crucial to choose the BESS rating with the adequate rating.

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