Adjustment Voltage Drop in Commercial with Photovoltaic and Battery Energy Storage System on Death End Distribution System

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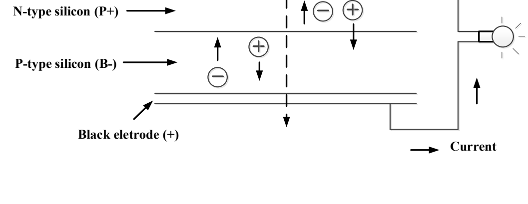
***Abstract*— This paper presents adjustment voltage drop in commercial with photovoltaic and battery energy storage system on death end distribution system. The objective to be adjusted the voltage drop on death end distribution system. The problem is voltage drop adjustment of distribution system with photovoltaic and battery energy storage system. Test system for the case study is a IEEE 12 bus radial distribution system. The results from the tests is install photovoltaic and battery energy storage system can adjust the voltage drop of the death end distribution system.**

Keywords—Voltage Drop, Commercial, Photovoltaic, Battery Energy Storage System, Death End Distribution System

I. INTRODUCTION

In commercial [1] electricity generates and distributes electric in distribution line to consumer. The power quality problem such as voltage drop or voltage surge can make electric device damage or dysfunctional. Voltage surge especially lightning strike can be solve problem by install the lighting rod. However voltage drop are different from voltage surge. The voltage drop can fluctuate when consumer consume the electric that can effect to other consumer by voltage not as normal IEEE standard this power quality problem happen in the death end of distribution line. Therefore photovoltaic are necessary to supply electric at the death end of distribution line return back to normal voltage.

In photovoltaic [2] system solar cell play role as electric generator that can generate in the sunlight. So when at night time and overcast weather is affect photovoltaic generation because of there is no sunlight. The battery storage discharge the electric in to supply line and recharge when photovoltaic can generate more than distribution line need. Sunlight energy conversion process on photovoltaic as shown in Fig. 1



In 1970 [3], This paper use solar cell array supply to charge battery and spacecraft load and converter high-voltage DC to low-voltage electronic with switching regulator. Use charger with trickle charge, cutoff mode, battery voltage and temperature limit in this workshop this solar cell array has tracker measure operating 125 voltage and supply power from 70 to 2580 watt. In 1979 [4], This paper experiment charge rate and discharge rate. Regarding memory effect, nickel cadmium is the best battery in photovoltaic application when compare to lead acid battery. Further this photovoltaic reliability system more than 12 years. In 1986 [5], This paper solar cell supplies power in telecommunication system. In telecommunication system need an availability energy anytime which mean the energy must continuously supply the system. Due to solar cell power generate dependent with solar rays which at night it and different season can fluctuate the energy. So solar cell in this paper use OPZS type battery. Life time use is 11 years. In 2000 [6], Solar cell in order to extend the battery life this paper install electric double-layer capacitors and two converters in the system. When solar cell generate electric first condition on it support electric to load and charge in EDLC and battery. This system give priority that EDLC supply the electric first after solar cell cannot generate and battery will discharge at last. In 2006 [7], This paper photovoltaic system the highest cost lifetime is battery. Because battery storage uses as lead acid in common. When battery recharge from very electric by photovoltaic generating. The life service of storage battery would be shorter form recharging and discharging. Maximum power point tracking manages battery system to charge and first converter. In 2007 [8], This paper present solar system with battery storage to improve reliability supply electric energy. Researcher install ultra capacitor on the solar system even when in the worst condition the solar system can still supply electric. Furthermore the ultra-capacitor has more advantage than battery to compensate electric supply back. In 2020 [9], there are study evaluate the distribution control methods of PV and BESS systems installed for controlling the supply-demand balance maintenance of a large number of power systems.

This paper presents adjustment voltage drop in commercial with photovoltaic and battery energy storage system on death end distribution system. Tested in IEEE 12 bus radial distribution system with a MATLAB program.

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II. PHOTOVOLTAIC

Photovoltaic [10] is one of renewable energy electric that can install on the rooftop of the building or even isolate places that has sunlight.

Thus the photovoltaic can improve the power quality problem at the end of electric distribution line. Furthermore photovoltaic power produce the clean and non-polluting power. It must be installed in sunlight conditions and connect to inverter before connecting photovoltaic in distribution system is shown in Fig. 2

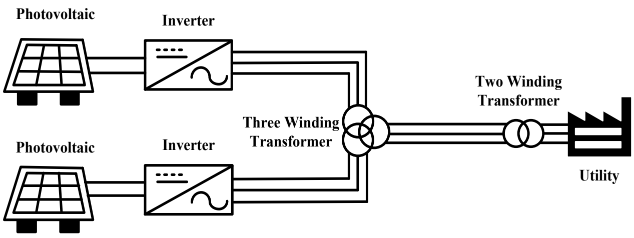

Fig. 2. Methods for generating electricity with solar cells.

From Fig. 3. The photovoltaic system consists of photovoltaic panels that generate electricity from sunlight into direct current electricity and inverter converts direct current to alternative current before feedback to distribution line. A schematic diagram of the photovoltaic system is shown in Fig. 3.

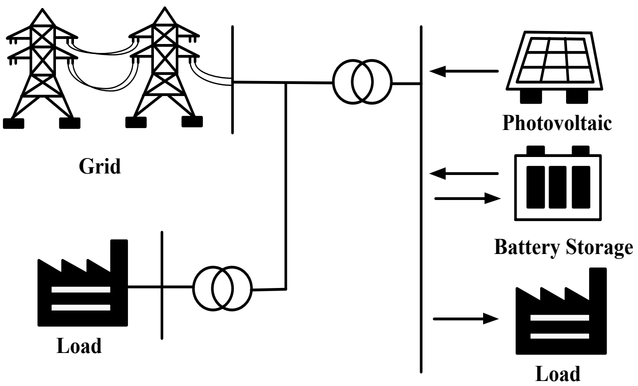

Fig. 3. Schematic diagram of the photovoltaic system.

III. INCREASING PERFORMANCE PHOTOVOLTAIC SYSTEM

PV system generate electricity depend on sunlight can be surplus the energy in distribution line. However, without sunlight PV cannot generate electricity which make grid supply the PV.

In order to increase reliability and efficiency. PV system combine with BESS together call hybrid photovoltaic system. Hybrid photovoltaic system as shown in Fig. 4.

From Fig. 4. Application hybrid photovoltaic increases the reliability and efficiency to photovoltaic system. In overcast weather day affect to photovoltaic electricity generation. BESS discharge electricity to load and increasing reliability of distribution system, when is happen emergency scenarios.

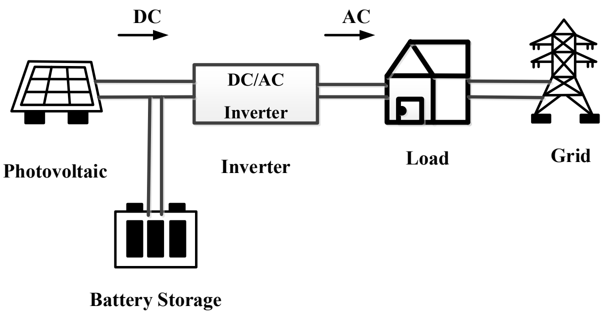

Fig. 4. Application hybrid photovoltaic increases the reliability and efficiency to photovoltaic system

IV. POWER LOSS AND REAL POWER

Power loss is an energy lost by unwanted heating and resistive component in distribution line which depend on length of the line, the size of the line, and the current through the line

Real power is represent an amount of energy consume to resistive circuit that convert from electric energy to other type of energy.

Power loss and real power is calculated in equation (1)-(3) [11].

$$\Delta P_{loss} = \sum_{t=1}^{T} (P_{loss_t} - (P_{loss}(P_{i,y,t}^{PV})(P_{i,y,t}^{BESS})) \quad (1)$$

Where
- ΔP_{loss} is defined as the total active power losses (kW)
- $P_{i,y,t}^{PV}$ real power produced by PV (kW)
- $P_{i,y,t}^{BESS}$ real power BESS (kWh)

$$P_{i,y,t}^{BESS} = Pbd_{i,y,t} - Pbc_{i,y,t} \quad (2)$$

Where
- $P_{i,y,t}^{BESS}$ real power BESS
- $Pbd_{i,y,t}$ is the power when charged at BESS while
- $Pbc_{i,y,t}$ is power when charging at BESS.

$$P_{i,t} = P_{i,t}^{load} - P_{i,y,t}^{PV} - P_{i,y,t}^{BESS} \quad (3)$$

Where
- $P_{i,t}$ real power required for the network
- $P_{i,t}^{load}$ real power demand
- $P_{i,y,t}^{PV}$ real power produced by PV
- $P_{i,y,t}^{BESS}$ real power BESS (kWh)

V. MODEL OF TEST DISTRIBUTION SYSTEM

The adjustment voltage drop in commercial with photovoltaic and battery energy storage system is tested with a IEEE 12 bus radial distribution system [12]-[13] to adjust the voltage drop. There are 1 feeders and 11 load points. Total load is 435 kW and 405 kVAr. Voltage base is 11 kV. Load data and line data as shown in Table I. and Table II. respectively. IEEE 12 bus radial distribution system is shown in Fig.5.

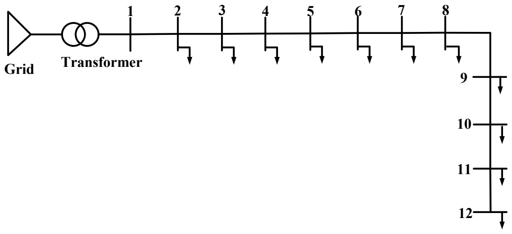

Fig. 5. IEEE 12 bus radial distribution system.

TABLE I. Load Data of IEEE 12 Bus radial Distribution System

Bus number	P (kW)	Q (kVAr)
1	0	0
2	60	60
3	40	30
4	55	55
5	30	30
6	20	15
7	55	55
8	45	45
9	40	40
10	35	30
11	40	30
12	15	15

TABLE II. Line Data of IEEE 12 Bus radial Distribution System

Bus number	Sending end bus	Receiving end bus	R (Ω)	X (Ω)
1	1	2	1.093	0.455
2	2	3	1.184	0.494
3	3	4	2.095	0.873
4	4	5	3.188	1.329
5	5	6	1.093	0.455
6	6	7	1.002	0.417
7	7	8	4.403	1.215
8	8	9	5.642	1.597
9	9	10	2.890	0.818
10	10	11	1.514	0.428
11	11	12	1.238	0.351

V. CASE STUDY

In this study is installed photovoltaic capacity 20 % of load requirement at bus voltage drop and installed battery storage capacity 20% of photovoltaic capacity at bus installation. Tested in 3 conditions is lightly load and normal load.

Case 1: no installation photovoltaic and battery storage

Case 2: installation photovoltaic and battery storage in bus 12. Information from TABLE I bus 12 load P result 15 kW. In light load 70 % load demand of 15 kW is 10.5 kW and installation photovoltaic capacity 20% of 10.5 kW is 2.1 kW and installation battery storage capacity 20% of photovoltaic capacity is 0.42 kWh. Case 2: installation photovoltaic 2.1 kW and battery storage 0.42 kWh is shown in Fig. 6.

Case 3: installation photovoltaic and battery storage in bus 10 11 and 12. Information from TABLE I bus 10 load P result 35 kW. Installation photovoltaic capacity 20% of 35 kW is 7 kW and installation battery storage capacity 20% of photovoltaic capacity is 1.4 kWh. In bus 11 load P is 40 kW. Installation photovoltaic capacity 20% of 40 kW is 8 kW and installation battery storage capacity 20% of photovoltaic capacity is 1.6 kWh. In bus 12 load P is 15 kW. Installation photovoltaic capacity 20% of 15 kW is 3 kW and installation battery storage capacity 20% of photovoltaic capacity is 0.6 kWh. Case 3: installation photovoltaic are at bus 10, 11 and 12 with capacity of PV 7, 8 and 3 kW respectively total capacity of PV 18 kW and BESS at bus 10, 11 and 12 with capacity 1.4, 1.6 and 0.6 kWh total capacity of BESS 3.6 kWh as shown in Fig. 7.

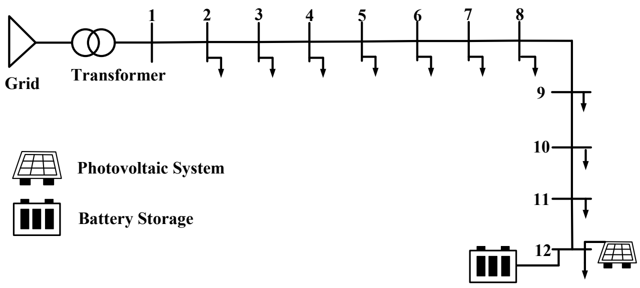

Fig. 6. Case 2: installation PV and BESS in lightly load.

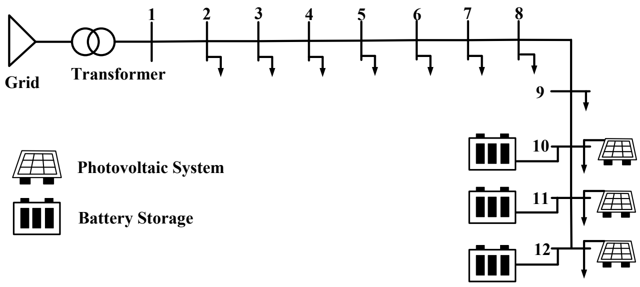

Fig. 7. Case 3: installation PV and BESS in normal load.

Location and capacity of photovoltaic and battery energy storage system as shown in Table III.

TABLE III. LOCATION AND CAPACITY OF PHOTOVOLTAIC AND BATTERY ENERGY STORAGE SYSTEM

Case	Bus installed PV and BESS	Capacity of PV (kW)	Total capacity of PV (kW)	Capacity of BESS (kWh)	Total capacity of BESS (kW)
1	-	-	-	-	-
2	12	2.1	2.1	0.42	0.42
3	10, 11, 12	7, 8, 3	18	1.4, 1.6, 0.6	3.6

The numerical results four case installed photovoltaic and battery energy storage system as shown in Table IV.

TABLE IV. RESULT INSTALLED PHOTOVOLTAIC AND BATTERY ENERGY STORAGE SYSTEM IN THREE CONDITIONS

Case	Power loss (kW)	Number of voltage drop bus	Total voltage drop bus	The lowest voltage	Voltage (p.u.)
1	18.83	10, 11, 12	3	11, 12	0.944
2	9.1	-	0	11, 12	0.963
3	17.18	-	0	12	0.950

The results adjustment voltage drop case 3 as shown in Fig. 8.

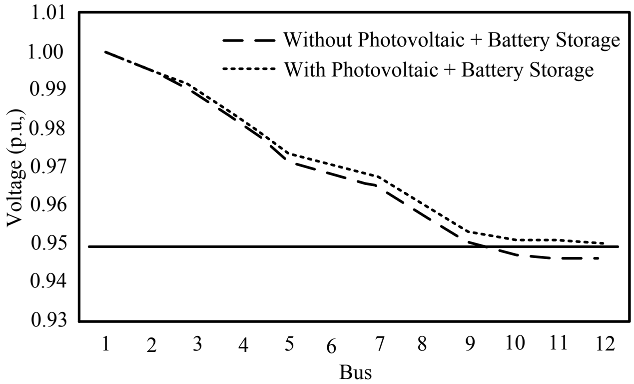

Fig. 8. Result adjustment voltage drop case 3.

From Fig. 8. When before installation photovoltaic and battery storage in normal load (100 % load demand) voltage drop at bus 10, 11 and 12. There for in case 3 need the installation PV and BESS at bus 10, 11 and 12. Total capacity is 8.4, 9.6 and 3.6 kW respectively. The result after installation PV and BESS found the voltage at bus 10, 11 and 12 was adjusted in standard (0.95-1.05 p.u.) and reduce power loss 1.65 kW.

VI. CONCLUSION

This paper presents adjustment voltage drop in commercial with photovoltaic and battery energy storage systems on death end distribution system. There were three test cases that follow, case 1: base case (no installation of photovoltaic and battery storage). Case 2: installation of photovoltaic and battery storage in light load (70 % load demand). And case 3: installation of photovoltaic and battery storage in normal load (100 % load demand). The results found that installation of photovoltaic and battery storage according to the level load demand conditions can adjust the voltage in death end distribution system.

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