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Study Committee C4

Title of Study Committee PS3

Paper ID_1057

The Transient Simulation of Battery Storage Connection to Utility Scale Solar Power Plant Under Low Inertia Scenarios in the Jordanian System

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Motivation

- The large integration of Variable Renewable Resources (VRE) into electrical system creates new challenges in the operation of electrical system, it becomes extremely important to find out how the power grid can handle these challenges and to know the ability of system to withstand any unexpected events that might occur on the network.
- In the last 10 years, Jordanian power system has been facing a huge integration of large-scale renewable resources (Wind / Solar) in the system such as the variability of the renewables and the huge difference between evening and morning peak load due to the increase in the distributed solar power plants, this problem appears in several conditions within year especially in spring and autumn time period.

Method/Approach

- The analysis results will show the effect of the proposed storage system on the distribution level in two study parts:

1. First Part: where BESS is tested in quasi-dynamic simulation for reserve power that is monitored at Point of Common Coupling (PCC),
2. Second Part: focuses on the contributions of BESS in case of simulated short circuit event at main bus and how changes in the BESS dynamic model under several conditions depending on the characteristics of Low Voltage Ride Through (LVRT) in the Jordanian grid code.

- The dynamic model is used for the quasi-dynamic and RMS simulations. Quasi dynamic simulation can be defined as a simulation tool for the execution of medium and long-term electrical studies but RMS simulation is a simulation tool to analyse the transient behavior under both balance and unbalance disturbance event conditions.

Objects of investigation

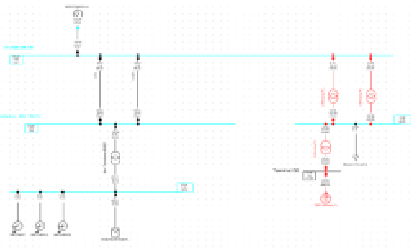
- Recently, power system planners investigate and assess the situation of electrical network. Part of that is by studying storage options such as Battery Energy Storage System (BESS) and how it could provide the requested grid services such as (smoothing power generation fluctuations, contribution in grid stabilization and reserve power reduction).
- The future increase of renewable projects in the eastern region of Jordan with the low forecasted load growth in the same area based on the category of demand that is mostly industrial demand, there will be a reverse power from the distributed network to the transmission network at several grid locations through day.

On the other hand, there are several scenarios with low voltage issues and could reaches collapse point in the eastern part of the Jordanian grid, the probability of similar event occurrence increased in future scenarios of night peak load conditions with no renewable penetration and limited generation in eastern area.

Experimental setup & test results

- This paper will focus on the impact of BESS and will demonstrate the significant objectives of the BESS in the proposed location in Mwaqar that is an area in the eastern part of Jordan, BESS has to absorb the excess power when BESS is located close to the loads and solve the variability issue as well as reduction of the congestion in the transmission network.

- The proposed connection of the BESS in Power Factory software is shown below. Masdar PV project is connected to Mwaqar Industrial substation that is a transmission substation in Mwaqar area via 132 kV Over-Head Transmission Line (OHTL) and the proposed BESS will be connected directly on the Mwaqar Industrial substation through step up transformers.



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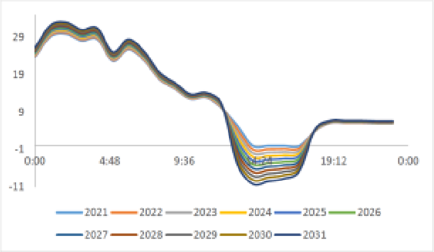
Case Study

- To investigate the impact of BESS, a Quasi-Dynamic Simulation (QDS) model for Load and the proposed BESS has to be build. The required parameters that are used in the BESS QDS model are state of charge (SOC), BESS energy size, initial state of charge, minimum and maximum state of charge, and the nominal storing of active and reactive power. On the other hand, the required parameters of the Load
- QDS model that is a time characteristic. Time characteristic of Load is a forecasted hourly active power based on the growth of demand and distributed renewables in Mwaqar, the load is defined as an aggregated demand and renewable generation from downstream networks. The time characteristics of the load in the chosen day for 24 hours of simulation interval as shown in Table below:

Time	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00
LOAD (2024)	24.4	30	30.8	28.9	29.3	23.4	26.5	23.6	18.3	15.6	12.8	13.2
LOAD (2031)	26.2	32.2	33	31	31.5	25	28.4	25.3	19.6	16.8	13.8	14.2
Time	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
LOAD (2024)	10.4	2.42	-2.95	-2.75	-2.56	-1.97	4.05	6.28	6.28	6.28	6.17	6.17
LOAD (2031)	11.1	-4.91	-10.2	-9.52	-8.84	-6.8	4.34	6.73	6.73	6.73	6.61	6.61

Time characteristics of Mwaqar Ind Substation Load.

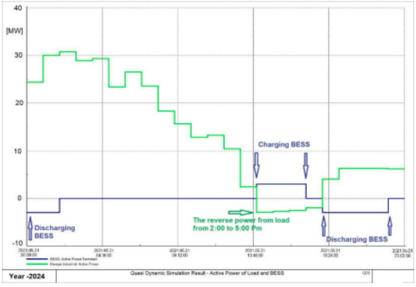
- In 2021, the total capacity of renewables installed in the distribution network of Mwaqar Ind substation reaches about 13 MW, all are solar projects. Also, the estimated solar power in the next 10 years will be increased to be higher than 23 MW. A specific day is chosen depending on the recorded data by the SCADA system for a spring day that shows a zero power through day hours in 2021, then the growth of the demand and the solar production growth will be applied to get the hourly load forecast.
- The spring day was chosen to highlight on the charging and discharging BESS behavior, and to show the considerable advantages of storage during off-peak load conditions in a low inertia system as shown in load profile below.



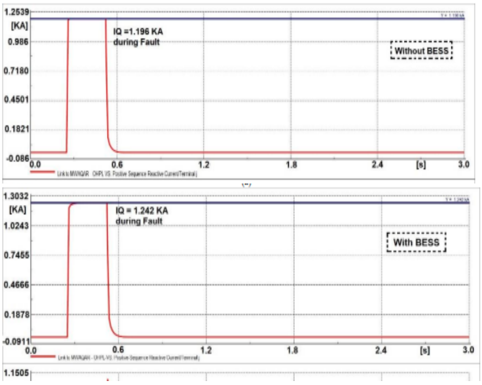
Load profile of MWAQAR IND substation 2021-2031

Discussion

- After adding all required inputs for performance of QDS models that are mainly for Mwaqar Industrial load and the proposed BESS, the behavior of the BESS is varied based on the load behavior. The proposed BESS can absorb 10 MW of the reverse power that injected from the renewables in the distribution network during day as shown in Figure below, that illustrates the behavior of battery in case the reverse power occurs in year 2024 and in 2031 because of small- scale solar projects in distribution side.



- A battery energy storage system (BESS) equipped with a suitably advanced inverter can perform reactive power control in addition to active power control. This allows a battery energy storage system to also provide reactive power support to the grid, and power factor control of loads when deployed in a microgrid, The value of positive sequence reactive power increases in studied scenarios, Vpcc equals 0.15, this increase will support the voltage at PCC during disturbances as shown below. the value of positive sequence reactive current (IQ) increases from 1.196 KA to 1.242 KA in case the voltage at PCC equals 0.15 P.u.



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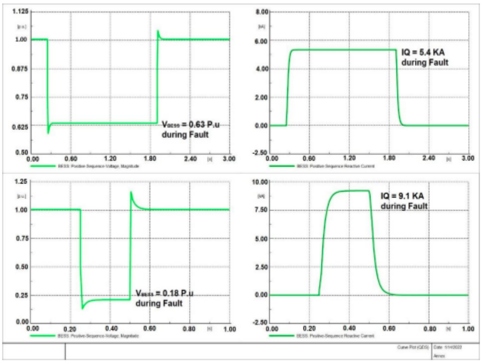
continued

Discussion(continued)

- Figure below show the result of reactive current contribution from BESS that will be propositional with the drop of voltage at the point of common coupling of BESS, the obtained results from two study cases of fault simulation at PCC that is Mwaqar HV substation clearly shows how the Battery supports the system with the requested ancillary service by injecting reactive current during voltage drop event.



- The results in the first part of study, QDS, demonstrate the need for BESS with operation time of 5 hours able to cover the reverse power during day hours, so the optimal BESS size in the studied location is 10 MW/5h when the growth of solar projects in this area becomes 10 MW in the next 10 years. The proposed BESS could be 3 MW/3h in case the operation time of BESS is in the following two years considering the storage age that is in average 10 years.
- Furthermore, the second part of the study, RMS simulation, the results show the reactive current contribution of the BESS during short circuit in the eastern area in Jordan depending on the LVRT characteristics as stated in Jordanian grid code that request any generator that is either conventional or renewable generation to support grid voltage by contributing in positive sequence reactive current during grid faults.

Conclusion

- In this paper, battery energy storage system is proposed to be connected in a substation that is located in eastern part of Jordanian transmission grid and near the area of utility scale solar power plant.
- The BESS is modelled in power factory simulation software including dynamic model and simulation of quasi-dynamic model of BESS and its behavior is checked when it is connected to a variant time characteristics load behavior with reverse power to the connected bus within day due to high penetration of solar power in distribution side of the same substation especially in spring and autumn season.
- Quasi-dynamic simulation results show the optimal size of the BESS that is suitable for solving the reverse power issue from downstream networks, the quasi-dynamic analysis presented in this paper shows that installed BESS system in the network helps in reverse power reduction in the studied time interval where BESS is charged at day when there is reverse power because of solar production a distribution level so that it will absorb unwanted reverse power at the connected bus, and then BESS discharged at night when there is no solar production and helps the system in case of substation night peak load conditions.
- In dynamic part, the same grid structure has been tested in RMS simulation of faults at PCC Main bus, simulated BESS in Mwaqar substation has the ability to ride through simulated sudden volage drop cases where the output result show how BESS could provide an extra help in low voltage ride through by injecting the required reactive power.