The Frequency Control in the islanded Micro Grid by using STATCOM Controllers

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ABSTRACT

When the distribution system is disconnected from the transmission system, the islanded portion of the network comprising DG (Distributed Generation) units forms a MG (Micro Grid). It is essential either to shut down the DG units or ensure the stable and the controlled operation of the islanded MG. The frequency and the voltage of the islanded MG vary when it is isolated from the main transmission grid. The voltage and the frequency of the islanded MG can be controlled to the permissible limits by providing the required amount of the active and reactive power by the local available sources in the MG. The main focus of this paper is about the control of the network frequency in the islanded MG by employing PI controllers based STATCOM (Static Compensator) and BESS-STATCOM (Battery Energy Storage System Equipped) devices. The study is done by using DIgSILENT power factory software version 15.0.

Key Words: Static Compensator, Battery Equipped Storage System.

1. INTRODUCTION

Islanding is a condition where the portion of the electrical power network containing DG units is isolated from the main power grid and continues to operate and energize the system network. The separation of grid could be due to many reasons such as the opening of breakers or other protection devices responding to the faulted condition. Apart from the serious issues of islanding (i.e. voltage and the frequency control, Islanding Detection ID, load control and protection etc. which are discussed in [1-2]), it can be used to improve the reliability of the power networks if the islanding related problems are carefully settled.

In the islanding, if there is load-generation imbalance, the frequency of the islanded MG deviates from its nominal values. If the active power loads demand of the islanded MG is higher than the active power production, the network frequency decreases and vice versa. On the other hand, if there is a deficiency of the reactive power in islanded portion of the network, the MG voltage decreases and vice versa. The current trend in the modern power networks is to operate islanded MG into stable and controlled manners by maintaining the constancy of the voltage and frequency of the network. This can be done by providing some of the ancillary services such as active and reactive powers in the local MG. All these tasks can be achieved if an appropriate control system is developed which should operate effectively in case of islanding.

The distribution set up proposed by the CIGRE (i.e. set up by the European experts) comprising WTG (Wind Turbine Generator), PV (Photovoltaic) solar generation units and energy storage devices used at the different locations of the CIGRE network has been taken for this research study. The one line diagram of the CIGRE network developed in DIgSILENT power factory software version 15.0 is shown in Fig. 1.

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This network comprises of two PV solar generation units of 3 and 4 kW connected at bus RC and RD respectively. There is one fixed-pitch fixed speed WTG of 5.5 kW connected at bus R19. The WTG is operated close to unity power factor by using a shunt capacitor. There are two batteries of 30 and 21 Kwh respectively connected at bus RA and at bus RB. These units are penetrated into the main power grid by using a 0.4 MVA, 20 kV/0.4 kV DyN transformer. The three phase unbalanced loads are integrated at the 0.4 kV voltage levels and are used at bus

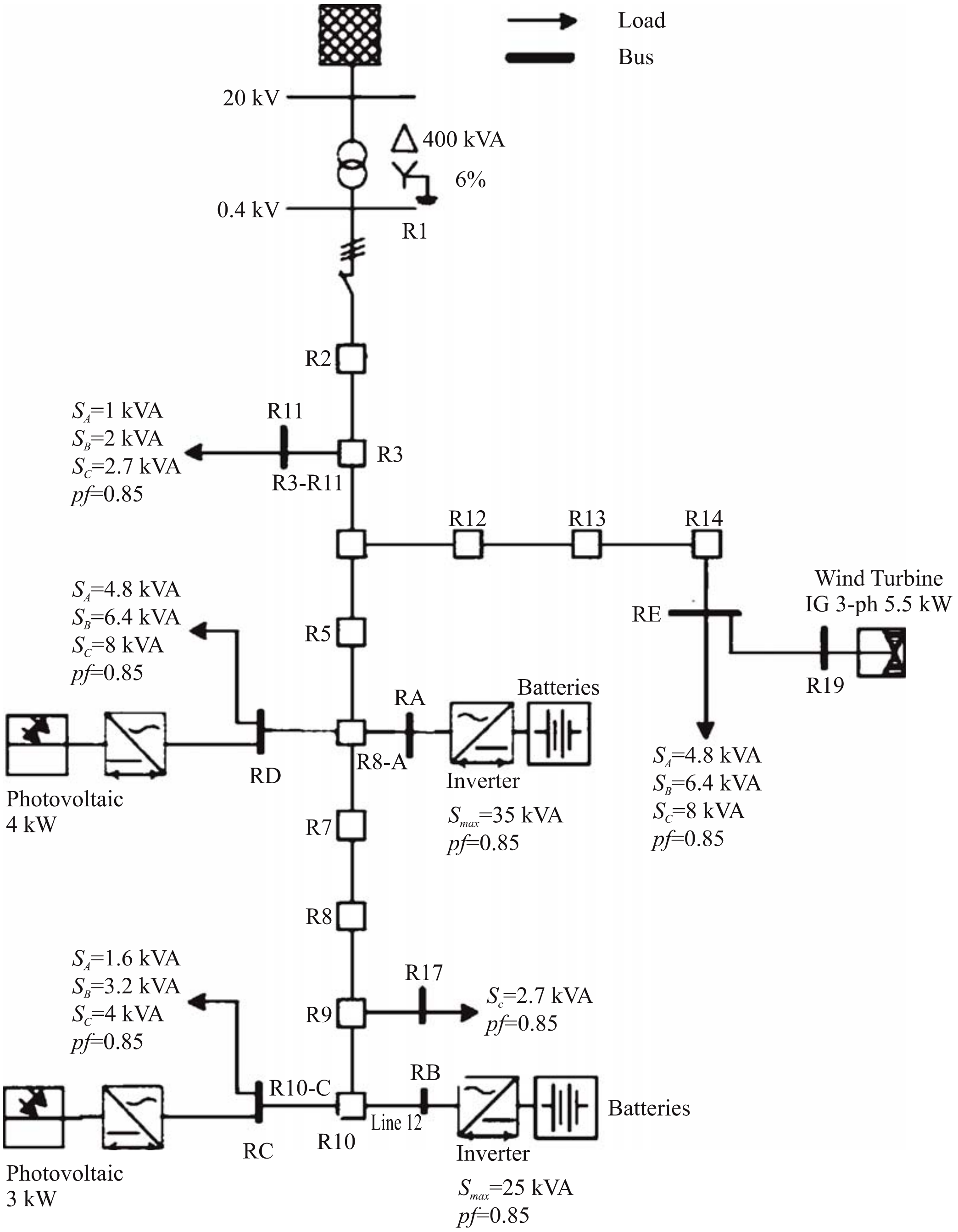

FIG. 1. THE CIGRE DISTRIBUTION SYSTEM TEST NETWORK [3]

RC, RD, RE, R11 and bus R17. The detailed information about the different parameters including distribution lines used in the network are given in Table 1.

Table 2 shows the parameters of the PI controllers used for two energy storage devices.

A lot of work is being done in the area of islanding and controlled operation of the islanded MG. The study about the islanding, its controllers design and the constancy of the voltage and frequency by applying load shedding technique in the islanded MG is presented in [5]. The voltage and the frequency control in islanded MG by using droop controllers are presented in [6]. The distributed secondary control scheme for unbalance compensation in droop controlled based islanding MG is described in [7-8]. Further work in the same area is done by using different techniques and can be found in [9-10].

The novelty of this paper is that it describes the clear concepts of controlling the frequency of the islanding portion of the network under this research study by using the advanced power electronics devices employing PI controllers.

The organization of this paper is as follows: section 2 gives a brief overview of the developed controllers which are able to control the problems of the frequency in islanded mode. Section 3 presents the simulation results in order to verify the frequency stability of the islanded MG. Finally, conclusion of the paper is presented in section 4.

TABLE 1. DATA ABOUT THE DIFFERENT CABLES USED IN CIGRE NETWORK

No.	Node	Type	Cross-Section (mm^2)	R_{ph} (Ω/km)	X_{ph} (Ω/km)	R_o (Ω/km)	X_o (Ω/km)	L (m)	Installation
1.	R1-R2	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
2.	R2-R3	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
3.	R3-R4	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
4.	R4-R5	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
5.	R5-R6	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
6.	R6-R7	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
7.	R7-R8	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
8.	R8-R9	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
9.	R9-R10	NA2XY	240	0.163	0.136	0.490	0.471	35	UG 3ph
10.	R3-R11	NA2XY	25	1.541	0.206	2.334	1.454	30	UG 3ph
11.	R4-RE	NA2XY	150	0.266	0.151	0.733	0.570	35	UG 3ph
12.	R6-RD	NA2XY	70	0.569	0.174	1.285	0.865	30	UG 3ph
13.	R10-RC	NA2XY	35	1.111	0.195	1.926	1.265	30	UG 3ph
14.	RE-R19	NA2XY	150	0.266	0.151	0.733	0.570	30	UG 3ph
15.	R8-RA	NA2XY	25	1.541	0.206	2.334	1.454	30	UG 3ph
16.	R9-R17	NA2XY	25	1.541	0.206	2.334	1.454	30	UG 3ph
17.	R10-RB	NA2XY	25	1.541	0.206	2.334	1.454	30	UG 3ph

TABLE 2. PARAMETERS OF PI CONTROLLERS USED FOR DIFFERENT BATTERIES USED IN CIGRE NETWORK

Name	Outer Controller	Inner Current Controller
Battery-1 controller	$K_p=1$ $K_i=0.002$ s	$K_p=0.7$ $K_i=0.001$ s
Battery-2 controller	$K_p=1.5$ $K_i=0.0021$ s	$K_p=0.6$ $K_i=0.001$ s

2. THE OVERVIEW OF THE DEVELOPED CONTROLLERS

When distribution system is grid connected the control system either works in Active power-Reactive power (PQ) mode or in Active PV (Power Voltage) control mode and depends upon the type of the application [4,11]. In the grid connected mode the controller of the battery-1 and battery-2 are developed as PQ control whereas, the control system of two PV units is in PV mode.

When the distribution system is disconnected from the transmission grid, the DG units must detect this islanding condition and one of the controllers should be switched to the VF (Voltage Frequency) control mode [4,12]. In case of islanding, the network loses it slack reference and this reference is established by the use of a VF controller. The VF controller is responsible to control the voltage at the PCC (Point of Common Connection) and the frequency of the network [4,12]. This is done if the desired amount of active and reactive power is produced by the control system of the suitable DG unit. A VF controller should be chosen for the DG unit which has a significant amount of energy available and a fast response. Since the PV and WTG based DG units are weather dependent and their power production is intermittent, a VF controller cannot be assigned to these units of the CIGRE network. A VF controller in this study is developed for the battery uni-t1 since it has higher energy content as that of battery unit-2. The control system of the other DG units operates in PQ/PV mode in islanding.

3. SIMULATION RESULTS AND THE DISCUSSION

In the normal operating conditions (i.e. grid connected mode), the total load demand in the LV test network is met by the grid, two PV units and one WTG. Table 3 show the power produced by the grid and the other DG units and the power consumption in the grid connected mode.

It can be seen in Table 3 that the main power grid of the CIGRE network delivers the active power of 84.45 kW in the grid connected mode as shown in Fig. 2.

TABLE 3. THE POWER PRODUCTION AND THE LOAD DEMAND IN THE GRID CONNECTED OPERATION

Active Power Produced by Generating Units (kW)				Active Power Consumed by the Loads (kW)			Power Losses (kW)
Grid	PV1	PV2	WTG	Battery-1	Battery-2	Other Loads	
84.45	3	4	5.5	28.7479	20.511	45.464	2.227
Total:	96.95			94.7229			

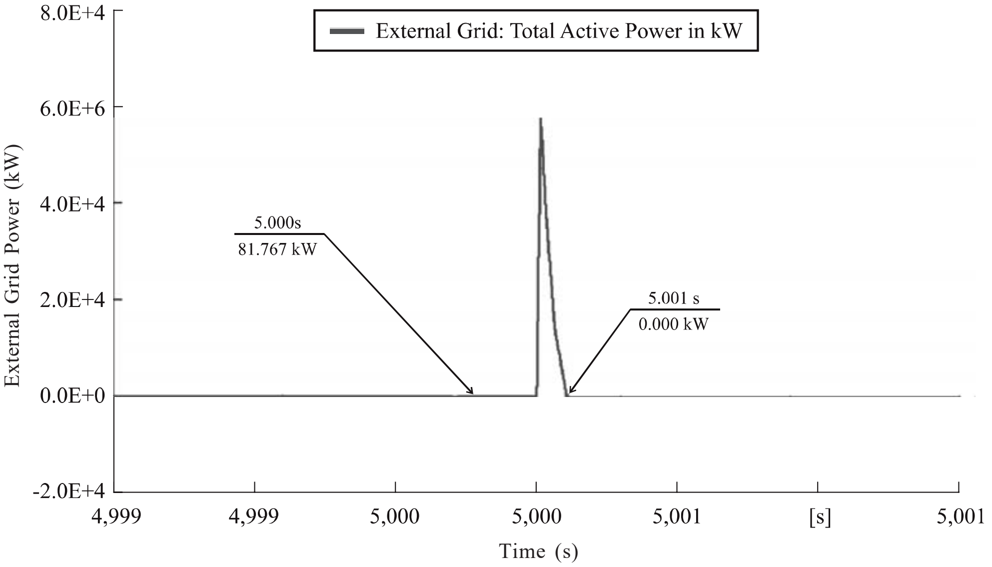

FIG. 2. THE ACTIVE POWER PRODUCED BY THE MAIN POWER GRID DURING GRID CONNECTED AND ISLANDED CONDITIONS

The main power grid delivers 84 kW of the power in order to meet the load demand and also to charge battery-1 and battery-2 of the CIGRE network. An overshoot in the grid power is observed at the time of the fault as shown in Fig. 2 and this is due to inrush current flowing to the faulted point.

When the distribution network is disconnected from the main grid, grid power becomes zero as shown in Fig. 2. The total demand of the CIGRE is met in this condition by all local DG units available there. The active power delivered by inverter of battery-1 and the active and reactive power of inverter of battery-2 is shown in Figs. 3-4.

It can be seen in Fig. 3 that battery-1 inverter absorbs 28.75 kW of the active power in order to charge the battery-1 in the grid connected mode. In case of islanding it delivers 31.77 kW of the active power in order to maintain the constancy of the frequency.

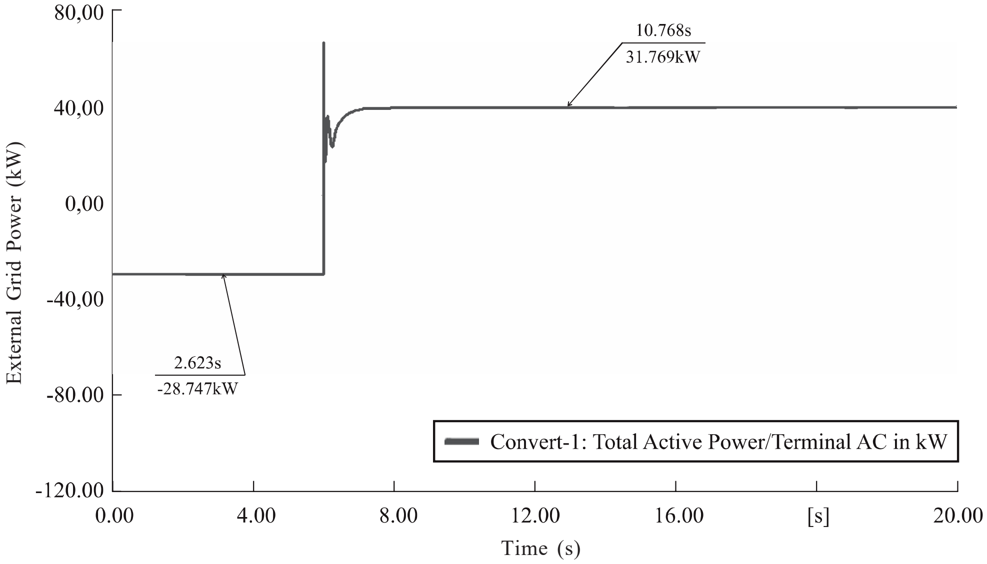

FIG. 3. ACTIVE POWER OF INVERTER OF BATTERY1 IN GIRD CONNECTED AND ISLANDED MODE

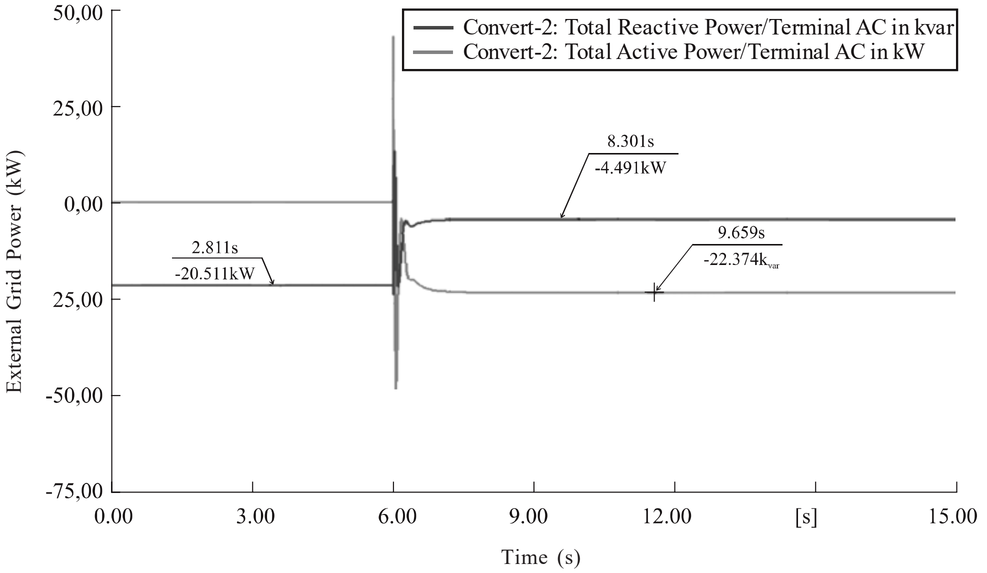

FIG. 4. ACTIVE AND REACTIVE POWER OF INVERTER OF BATTERY2 IN GIRD CONNECTED AND ISLANDED MODE

A battery-2 inverter absorbs 20.5 kW to charge battery-2 in the grid connected mode as shown in Fig. 4. The control system of this inverter is developed with the voltage control priority [4] so its main responsibility is to control the voltage at the point of the connection during islanding. In islanding this inverter absorbs 22.73 kvar of the reactive power. The active power produced by the DG units and the load demand in islanded MG is shown in Table 4.

Hence, the frequency of the islanded MG is controlled by providing the active power by the available local DG units of the CIGRE network and is shown in Fig. 5. The different peaks highlighted in the frequency plot as shown in Fig. 5 are due to different events and are labeled on the diagram.

Figs. 6-7 tell about how long time islanded MG can survive in islanding. Fig. 6 tells that if initial SOC (State of Charge) battery-1 is at 50%, then MG can survive up to about 1091 s when it is discharged down to 20% due to economic reasons [13].

It can be seen in Fig. 7 that when initial SOC of battery-1 is considered to be 95%, it takes long time to support the islanding MG and runs it for about 2715s (i.e. 45.25 minutes) in a stable condition when it is discharged down to 20% [13].

4. CONCLUSION

The study about the islanding conditions together with the development of the control system for the specific DG unit of the CIGRE LV distribution network is proposed in this research paper. The developed controllers of the local available DG units have ensured the constancy of the frequency in the islanded MG. It is also shown that if the

TABLE 4 . THE ACTIVE POWER PRODUCED BY DG UNITS AND LOAD DEMAND IN ISLANDED MG

Active Power Produced by Generating Units (kW)				Active Power Consumed by the Loads (kW)		Power Losses (kW)
PV1	PV2	WTG	Battery-1	Battery-12	Loads	3.74
3	4	5.45	31.769	4.491	35.99	
Total:	44.219			40.48		

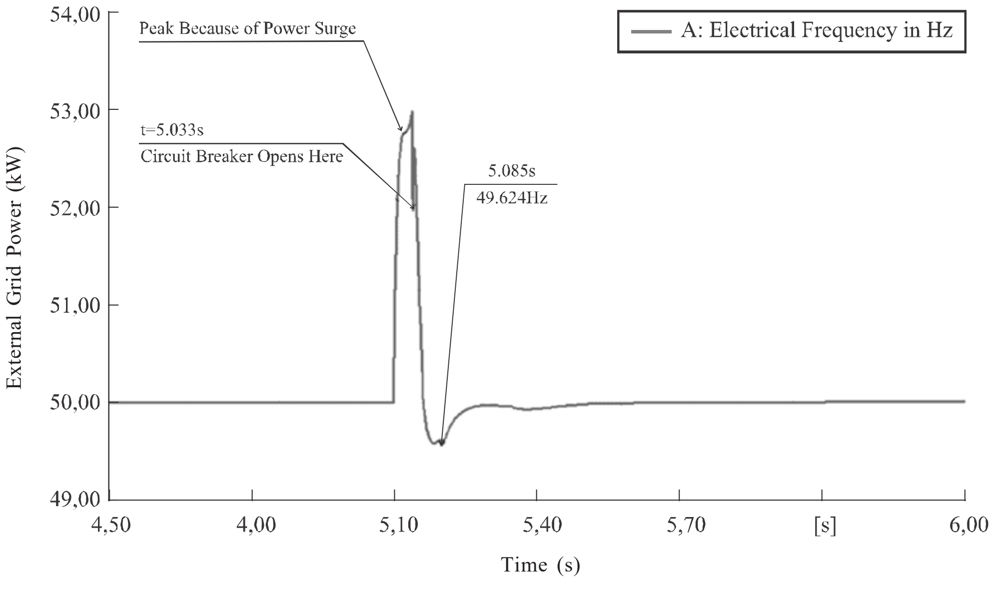

FIG. 5. THE NETWORK FREQUENCY IN CASE OF THE GRID CONNECTED AND ISLANDING MODE

battery-1 is fully charged it can support the islanded MG for about 45.25 minutes to run it into a stable condition even in islanding.

The study about the effects of the voltage dip and voltage unbalance on WTG and PV units together with the study of N-2 contingency analysis in islanded MG will be the future research topics of the author.

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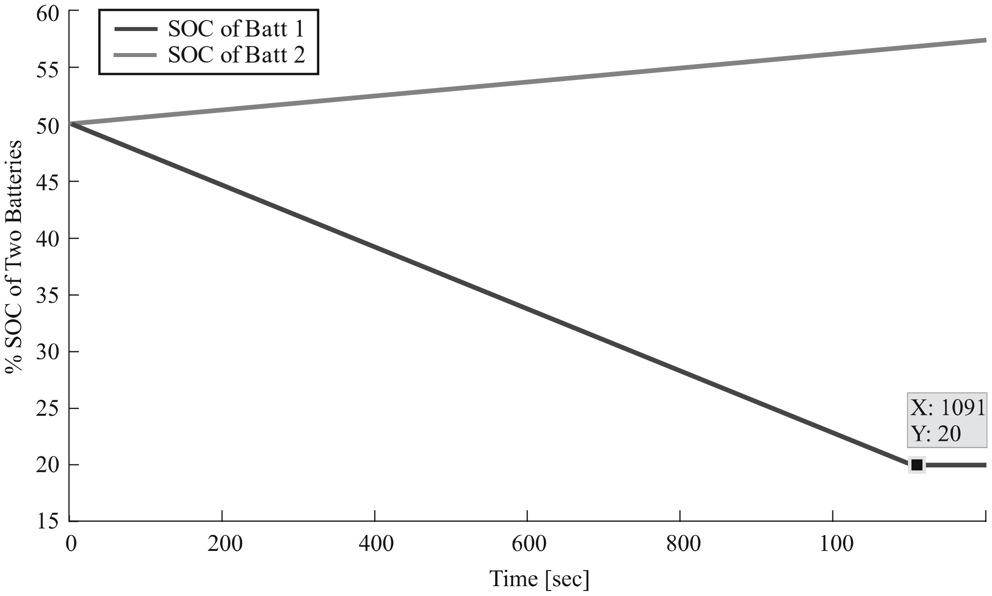

FIG. 6. THE %SOC OF BATTERY-1 AND BATTERY-2 WHEN IT HITS THE FINAL DISCHARGING LIMIT IN CASE WHEN INITIAL SOC=50%

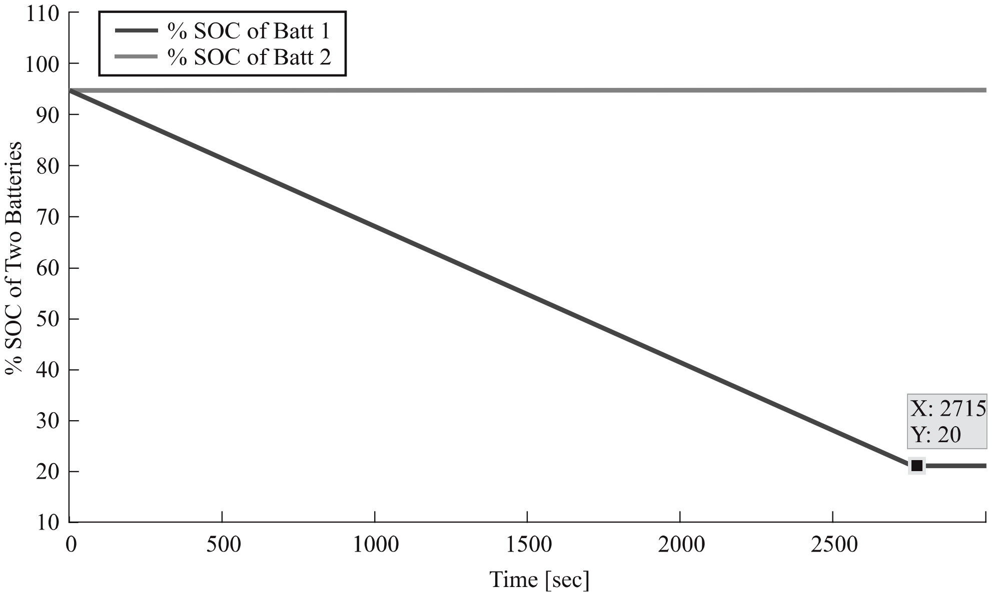

FIG. 7. THE %SOC OF BATTERY-1 OF BATTERY-2 WHEN IT HITS THE FINAL DISCHARGING LIMIT WHEN INITIAL SOC=95% IS CONSIDERED

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