ANALYSIS OF UTILIZATION BATTERY ENERGY STORAGE SYSTEMS FOR FREQUENCY REGULATION

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ABSTRACT

The possibility of dynamic energy storage such as auxiliary function FACTS regulator offers to control flows of active and reactive power in an attachment point to the system. Dynamic control of active and reactive power is running independently from each other. Reactive regulation power provides voltage control and network stability with a huge dynamic response. Integration possibilities of energy storage in a chemical form into the storages, has a potential to bring significant advantages for the transmission operators and distributional networks. Increasing distributed share production, which is based in part on the renewable energy sources, leads to the storage need for some needs that offer ancillary services and allow reliable, cost – effective and quality electricity supply. In this paper, we present a method which allows to keep the optimal amount of SoC. deal with SoC level balancing (to 50%) by identifying Active Frame (AF), Frame of Charge (FoC), Frame of Discharge (FoD), SoC deflection predictions and its balancing with as little DoD cycle change as possible.

Keywords: *BESS, EoL, SoC, DoD, VSC, FoC, FoD*

1. INTRODUCTION

Power reserve sequence is intended for the situation, when we have to deal with sudden, unexpected shortfalls in the production or in the electricity transmission and also with a sharply increasing load. Primary, secondary and tertiary regulation reserve is gradually available in time reserve disposition. Primary regulation of active power maintains a balance between the production and electricity consumption within synchronous area, which is using the speed regulation or active power device that provides the ancillary services. The activity aim of all interconnected power systems is operational safety energy system in a synchronous area and it is stabilizing system frequency to the equilibrium value after some damage within the time of frame seconds, but without the recovery set point frequency system and the scheduled exchanges of active power. For the year 2013 the contribution of Slovakia was under the common transmission network ENTSO-E $\pm 29\,\mathrm{MW}$ [1]. Accumulating battery systems should absorb or supply the energy according to the same demands like a present providers PRV (Primary regulative power) in a real time without delaying, which is typical for rotating machines. The frequency range of the primary regulation active power will be $\Delta f = \pm$ 200 mHz and the non – sensitivity zone of the regulator and active power device, which provides primary regulation stays at the value of $\eta < \pm$ 10 mHz. To compare the lifetime changes, we will evaluate the primary regulation model of the non – sensitivity zone $\eta < \pm$ 20 mHz [2].

Battery energy storage systems (BESS) that are connected on the secondary side through the transformer phase to the distribution network represents an alternative to traditional maintenance strategy of an adequate margin – call backup for the reduction of frequency fluctuations. In response to frequency deviations, the systems for the energy accumulating can deliver primary regulation power (primary reserve). It means that fixed energy which is placed into the several cycles for some time allows to the transmission network operators to decreasing or removing the purchase need and ancillary services of primary regulation which is provided by conventional providers.

The FACTS systems with an accumulation combine the storage of energy in high-voltage lithium-ion battery with static reactive power compensator for the compensation and for the reactive power and the dynamic voltage control. The technology which is called Voltage Source Converter (VSC) has an advantage, because it is able to change operating point. It means that it can work in four quadrants and manage independently active and reactive power. STATCOM with an energy accumulation, it is able to regulate reactive power like an ordinary SVC, and also an active power thanks to batteries which can be used like a support of dynamic stability and distribution network by the most effective combination of active and reactive power [3].

2. STORAGE SYSTEM FOR FREQUENCY CONTROL

As we have already known, STATCOM is a static synchronous compensator that is used like a reactive power regulator. With STATCOM the absorbed reactive power can be changed, while in contrast to the SVC systems, it does not contain any mechanical switching elements and it is able to cope with a much faster changes, for example voltage or fast change of reactive power flow.

The energy accumulation, which can be a STATCOM part, is based on the battery chain. The huge energy amount is needed and the demanded time of discharging and charging is in a range from several minutes to several hours [4, 5], the batteries are connected into series for getting demanding voltage and then parallel demanded power. The picture no.1 illustrates STATCOM systems with BESS, which consists of VSC and with serially connected battery rows on one side for achieving higher power. Every battery series consist of series – connected batteries to achieve the desired voltage level.

If the minimum requirements do we consider arranging the batteries and making them able to supply/demand $\pm 2\,\mathrm{MW}$, the active power during 15 minutes, then the minimum energy capacity of the batteries is 2 MWh. The charging level system (*SoC*) is maintained at the level about 50 % of the whole capacity. The energy accumulation is designed for the energy capacity 2 MWh to ensure sufficient margin for PRV and also to cover the capacity losses. Table 1. describe activated regulation power of BESS depends on frequency deviation.

The battery cell has a discharging power 146 W to the one cell. For the energy capacity 2 MWh there is needed the minimum battery cells at the number 13698 [7]. Parallel battery chains provide one way nominal converter voltage and the flow, which is needed in a discharging time. 13698 installed articles are then divided into two orders. In the consideration formats, there is installed battery capacity system 2 MWh.

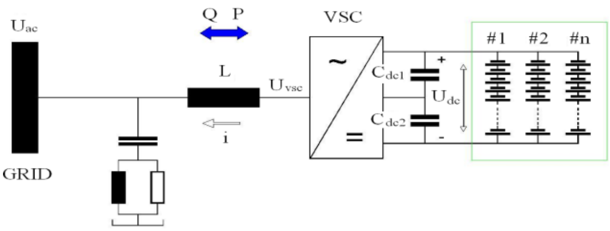

Fig. 1 Schematic layout of STATCOM with Energy Storage

If we are aware with the PRV granting condition, the maximal power must be able at least for 15 minutes, after those it will be activated secondary frequency regulation. In transmission network terms, the storage system can with the reduced accumulation demand some acts that can be repeated pretty often, because the interventions for changing power levels avoid imposing too much power on one side or another side. The methodology which was chosen to maintain the batteries within the limits *SoC* is counting with 50 % reserve, that covers losses of the battery capacity and with and regulative algorithm, in which each successive 15 minute interval balances *SoC* at the level of 50 %.

In battery terms, it has a restriction on the degree SoC charge two main consequence. At first, every charging and discharging cycle will represent bigger percentage share of installed energy, which means that the cycle can be used even faster. The second thing is that the fluctuations in the ratio of the depth and discharge (*DoD*) during charging and discharging can be too high to be compatible with long-term battery life. For ordinary Li – ion batteries with a graphite negative electrodes, the charging and discharging at high values *DoD* can lead to significantly premature aging, which is caused by the lithium plating processes [8]. The acceptable power during the charging and discharging is the battery type function. The next factor is that the BESS systems can be lighter in balanced position if they can provide multiple values energy at the slightest fluctuations into positive or negative *DoD*.

3. POWER-FREQUENCY RESPONSE OF THE STORAGE SYSTEM

The picture no.2 illustrates the frequency process (left) in a time and the characteristics of primary frequency regulation (right). In a time, when the frequency is in a non – sensibility process, at the upper border, the battery is charging. If the frequency is under the lower limit in a non – stability process, the battery is discharging.

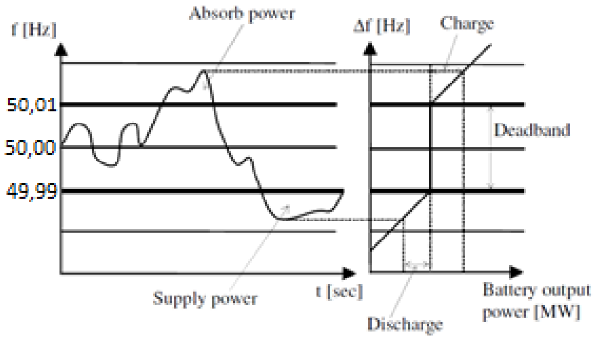

Fig. 2 Operation principle

While the frequency deviation at nominal frequency 50 Hz can be positive or negative, the battery accumulation SoC should by in a position when it allows discharging at any time ($f_{(t)}$ <49,99Hz), and also charging ($f_{(t)}$ >50,01Hz). For this reason the normal battery charging level *SoC* is 50 %. It is because after the discharging cycle, there may appear another discharging cycles and the battery accumulation can finish as absolutely discharged. The *SoC* level will achieve the border of *SoC* min. Similarly there can appear some several consecutive cycles and the battery accumulation will achieve the level of *SoC* max.

It should be noted that the operations in picture no.3 is due to the fact that the frequency has not gone the whole time through the non – sensitivity zone. These operations in the non – sensibility zone represent η < ± 10 mHz 57,44% the total amount of cycles, in non –sensibility zone η < ± 20 mHz 77,28% the total amount of cycles. The operations in the non – sensibility zone are not counted into the capacity losses. To keep the battery in the middle of *SoC* zone, it demands the independent power for charging or discharging, when the frequency in non – sensibility zone or when the *SoC* level is out of tolerance level, which is at this case estimated value from 45% to 55%.As we can see in the picture no.4 , in the analysed week there was BESS in most cases in the range, where the *SoC* value exceeded the 55 % value, which is causes by the frequency deviations occur predominantly in $f_{(t)}$ >50,00Hz.

If the frequency is in non – sensibility zone, the battery power has a value that corresponds with the battery level, which is in our model maintained at *SoC* level of 45-55%.

Regulation power supplied $f(t)$ < 49,99Hz:

$$P_{\mathrm{dod}} = \int_{t=1}^{900} P_{\mathrm{dod}}(t)dt \qquad (1)$$

Consumed regulation power $f(t) > 50{,}01$Hz:

$$P_{\mathrm{odob}} = \int_{t=1}^{900} P_{\mathrm{odob}}(t)dt \qquad (2)$$

Similarly , when the frequency is in non – sensibility zone and if the battery charging level is under the minimal value, which is in this case 45 %, the battery is charging according to *SoC* so that in the next 15 minute interval will be able to achieve the balance. The plane of the zero power in the sketch is continuously rising and decreasing and creating a black area in the picture no.3.

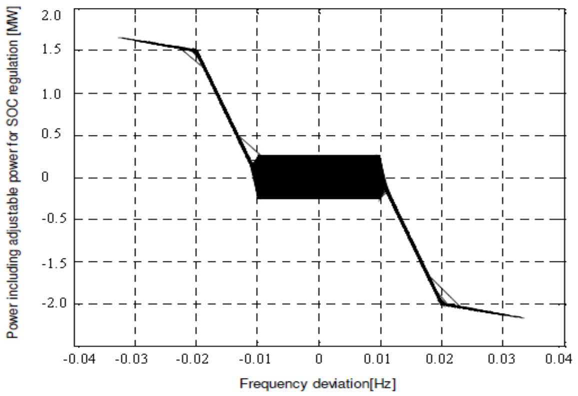

Fig. 3 Power-frequency characteristic having

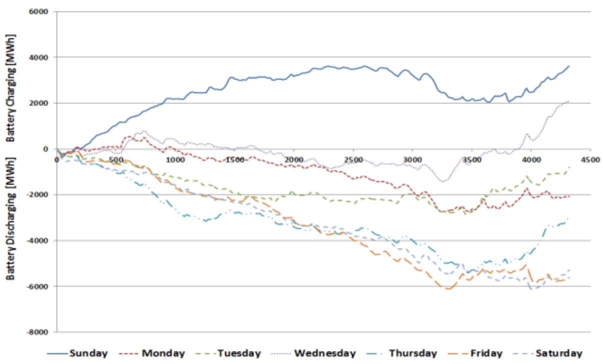

Fig. 4 SOC level as a function of time for week

The *SoC* levels in the picture no. 4 in the analysed week lied between 5% and 99% of the battery capacity value, thus the deployability condition is made for the supply of primary control power. The battery accumulation ±2MWh is fine for the frequency regulation in simulation area.

SoC calculation:

$$SoC_{\mathrm{avg}} = \frac{1}{\Delta t}\int_{t_{n-1}}^{t_n} SoC(t)dt \qquad (3)$$

4. ESTABLISHMENT OF A CONTROL CIRCUIT SOC

Picture no.5 illustrates the imposing regulation *SoC*, where the *f* is a network frequency and *P* is the power according to the characteristics. 1 and *SoC* is the charging level.

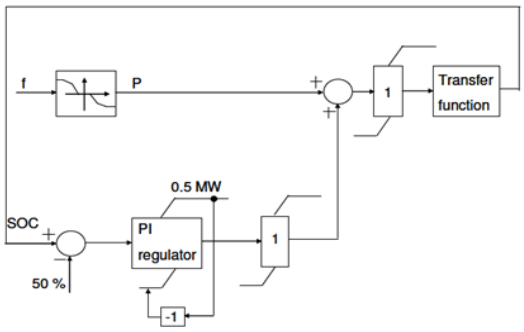

Fig. 5 *SoC* level as a function of time for week, having a *SoC* control loop

To evaluate bigger *SoC* powers, it is necessary not to notice minor capacity fluctuations in the non – sensibility zone. The filtration level of course, will influence the results. The inclusion of the filtration level in non – sensibility zone covers the losses that are connected with keeping the system at 50 %. In order to keep the level of the *SoC* operating point, the whole power $P_{\mathrm{ext}}(t)$ is counted as a sum $P_{\mathrm{AS}}(t)$ (ancillary service) and a operating point BESS signal $P_{\mathrm{WP}}(t)$ (operating point).

$$P_{\mathrm{ext}}(t) = P_{\mathrm{AS}}(t) + P_{\mathrm{WP}}(t) \qquad (4)$$

The resulting power is counted as a *SoC* difference between maximum and minimum, which is achieved in a 15 minutes interval, which can be later expressed as a power PAS (t) by the capacity unit [MW/MWh].

5. THE LIFE CYCLE OF LI-ON BATTERY

Batteries degrade predictably when they are submitted of controlled repeated charging and discharging cycles. Picture no.6 illustrates the life-cycle curve of Li-ion battery system, based on the *DoD* depth discharging for every cycle [6,7].

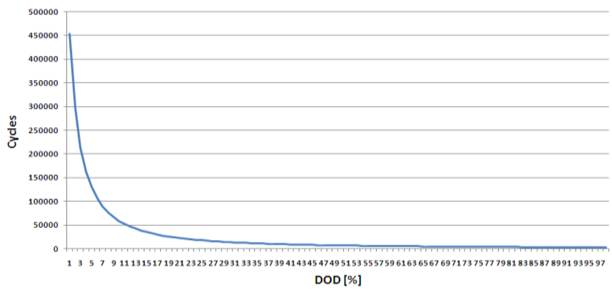

Fig. 6 Cycle-life curve for the lithium-ion battery system

The capacity loss calculation:

$$y = 2498 \cdot x^{-1483} \quad R^2 = 0{,}999 \tag{5}$$

R^2 is the real component of giving depth to the battery discharge *DoD* and *y* is the number of cycles pertaining to the value of *DoD*.

The capacity losses sum:

$$EoL_{\mathrm{TOTAL}} = \sum_{i=1}^{n} EoL(cyc)_i \tag{6}$$

Calculating the level of battery power:

$$\Delta E(t_i) = \frac{[MW(t_i) + MW(t_{i-1})].(t_i - t_{i-1})}{2} \tag{7}$$

$$SOE(t_i) = SOE(t_{i-1}) + \frac{\Delta E(t_i)}{\mathrm{Battery\_ratting(MWh)}} \tag{8}$$

Calculation the end of capacity in days:

$$EoL = \frac{\left(\frac{\Delta EoL}{50}\right)}{T} \tag{9}$$

6. ANALYSIS DURING FREQUENCY CONTROL USING BESS

In the analysed week 37/2012 we applied the calculation for every day separately, and we compared introduction of two non – sensibility zones $\eta < \pm$ 10 mHz; $\eta < \pm$ 20 mHz. Picture no.7 illustrates the hour process of analysed frequency.

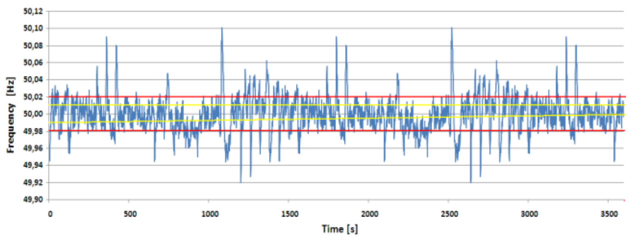

Fig. 7 Hour of analysed frequency

In the picture no. 9 we can see the frequency process, which is divided by algorithm cycles, where the end of the cycle is always bounded by the frequency value change, caused by rising and falling. Picture no. 8.

$f_{(t)} > 50{,}01$Hz $\quad f_{(t)} < f_{(t+1)} \rightarrow$ cycle '+'
$\quad\quad f_{(t)} > f_{(t+1)} \rightarrow$ cycle '-'
$f_{(t)} < 49{,}99$Hz $\quad f_{(t)} > f_{(t+1)} \rightarrow$ cycle '-'
$\quad\quad f_{(t)} < f_{(t+1)} \rightarrow$ cycle '+'

For better imagination, in the picture no. 9, there is showed only the biggest of 30 cycles in the analysed hour. In one cycle, the difference of deviations system in frequency Δf according to Tab. 1.

Table 1 indicates the value of primary activated regulation power.

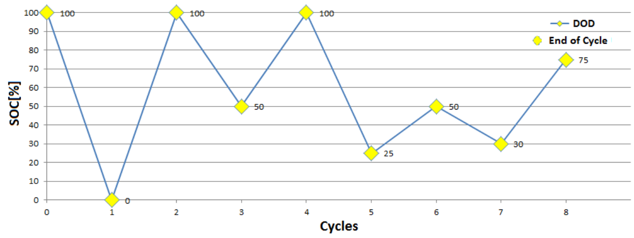

Fig. 8 Identified of cycles according *SoC* level

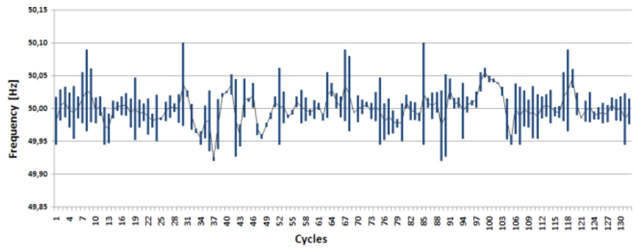

Fig. 9 During the division of frequencies to cycles

Table 1 Dependence of regulation power from the system frequency deviation

Activation time [0-30s]	Positive frequency difference [Hz]	Negative frequency difference [Hz]	Activated regulation power without BESS [MW]	Activated regulation power with BESS [MW]	Percentage charge / Regulation power [%/MW]	Activated regulation power overall [MW]
1	50,00667	49,99333	0,9	0,07	3,3333	0,97
2	50,01334	49,98666	1,8	0,13	6,6633	1,93
3	50,02001	49,97999	2,7	0,20	9,9933	2,90
4	50,02668	49,97332	3,6	0,27	13,3233	3,87
5	50,03335	49,96665	4,5	0,33	16,6533	4,83
6	50,04002	49,95998	5,4	0,40	19,9833	5,80
7	50,04669	49,95331	6,3	0,47	23,3133	6,77
8	50,05336	49,94664	7,2	0,53	26,6433	7,73
9	50,06003	49,93997	8,1	0,60	29,9733	8,70
10	50,0667	49,9333	9	0,67	33,3033	9,67
11	50,07337	49,92663	9,9	0,73	36,6333	10,63
12	50,08004	49,91996	10,8	0,80	39,9633	11,60
13	50,08671	49,91329	11,7	0,87	43,2933	12,57
14	50,09338	49,90662	12,6	0,93	46,6233	13,53
15	50,10005	49,89995	13,5	1,00	49,9533	14,50
16	50,10672	49,89328	14,4	1,07	53,2833	15,47
17	50,11339	49,88661	15,3	1,13	56,6133	16,43
18	50,12006	49,87994	16,2	1,20	59,9433	17,40
19	50,12673	49,87327	17,1	1,27	63,2733	18,37
20	50,1334	49,8666	18	1,33	66,6033	19,33
21	50,14007	49,85993	18,9	1,40	69,9333	20,30
22	50,14674	49,85326	19,8	1,47	73,2633	21,27
23	50,15341	49,84659	20,7	1,53	76,5933	22,23
24	50,16008	49,83992	21,6	1,60	79,9233	23,20
25	50,16675	49,83325	22,5	1,67	83,2533	24,17
26	50,17342	49,82658	23,4	1,73	86,5833	25,13
27	50,18009	49,81991	24,3	1,80	89,9133	26,10
28	50,18676	49,81324	25,2	1,87	93,2433	27,07
29	50,19343	49,80657	26,1	1,93	96,5733	28,03
30	50,2001	49,7999	27	2,00	99,9033	29,00

Estimated battery life on basis of identifying the sub – cycles then comes from the chart during the battery life. In the picture no. 6, where is for every cycle, which is based on the *DoD* assigned the capacity loss. The individual losses sum creates the total capacity loss of BESS. It is important to realize that this value is constantly decreasing and it decreases the total available power system. If we consider, that in 50 % of the capacity loss we will have to replace individual battery cells or decrease minimum possible PRV, we must take into account this parameter also in determining the economic benefits by BESS.

Table 2 Identified sub cycles $\eta < \pm$ 10 mHz

Center SOC	SOC Swing	Micro Cycles per day	Capacity loss [%]
0,01	<2%	2657	0,003215338
0,03	2~4%	1145	0,00252804
0,05	4~6%	0	0
0,07	6~8%	621	0,003832635
0,09	8~10%	151	0,001700302
0,125	10~15%	35	0,000679913
0,175	15~20%	12	0,000332519
0,25	20~30%	4	0,000199152
0,35	30~40%	0	0
0,45	40~50%	0	0
0,55	50~60%	0	0
0,65	60~70%	0	0
0,75	70~80%	0	0
0,85	80~90%	0	0
0,95	90~100%	0	0
Total capacity lost per day [%]			0,012487899
Total capacity lost per year [%]			4,558083193
Years to -50% capacity (yrs)			10,96952335

Table 3 Identified sub cycles for $\eta < \pm$ 20 mHz

Center SOC	SOC Swing	Micro Cycles per day	Capacity loss [%]
0,01	<2%	3573	0,004323825
0,03	2~4%	712	0,001572021
0,05	4~6%	0	0
0,07	6~8%	261	0,001610818
0,09	8~10%	58	0,000653096
0,125	10~15%	15	0,000291391
0,175	15~20%	4	0,00012107
0,25	20~30%	2	9,05482E-05
0,35	30~40%	0	0
0,45	40~50%	0	0
0,55	50~60%	0	0
0,65	60~70%	0	0
0,75	70~80%	0	0
0,85	80~90%	0	0
0,95	90~100%	0	0
Total capacity lost per day [%]			0,008662769
Total capacity lost per year [%]			3,161910616
Years to -50% capacity (yrs)			15,81322374

The Tables 2. and 3. Illustrates the division of cycles according to the *SoC* displacements for analysed day 9.9.2012, where the difference between the non – sensibility zones will cause displacement cycle towards lower deflections *SoC* and thus to a minor capacity loss.

Picture 10. shows us how to keep the system capacity at equilibrium state, we inducted a regulatory circuit using the fact that after 15 minutes of supplying PRV, secondary frequency regulation will be activated and capacity deflection from 50 % *SoC* will be regulated in the next 15 minutes.

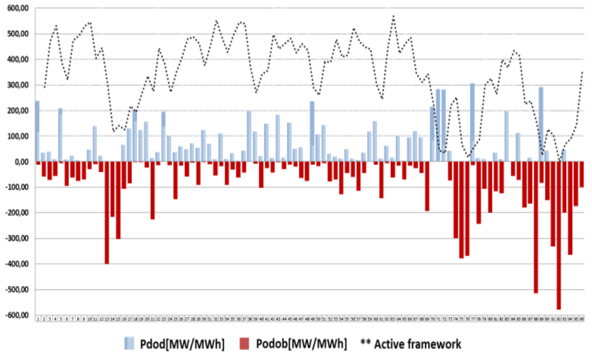

Fig. 10 15-minute levels of supplied/taken off power and Active framework

As batteries supply regulation power only when the frequency overpasses the dead zone level $\eta < \pm$ 10 mHz, the power needed to balance the capacity will only be active outside of this interval. *AF* (Active Framework) is the time during which the system supplies/takes off power.

For every following 15-minute intervals we will supply *FoC* (Frame of Charge) or take off *FoD* (Frame of Discharge) power unit to balance *SoC* 50 % following this formula:

$$FoC = \frac{\sum_{t=1}^{900} P_{TARGET\ (odob)t}}{AF} \tag{10}$$

$$FoD = \frac{\sum_{t=1}^{900} P_{TARGET\ (dod)t}}{AF} \tag{11}$$

After the capacity change, in the first 15 minutes we will balance *SoC* 50% following the formula $P_{ext}(t)=P_{AS}(t) \pm P_{soc}(t)$ where in the next 15 minutes of regulation we will supply/take off *FoC*/*FoD* unit in every *AF* to the required regulation power; we use the presumption that:

$$\sum_{t=901}^{1800} AF_t > \sum_{t=1}^{900} AF_t \tag{12}$$

As Table 4. shows us if the total *AF* in the time t=(901,1800) is lower than the one in the previous interval, the total needed power to balance *SoC* 50 % was not supplied. The difference between the real P_{REAL}(MWh) and required power P_{TARGET} (MWh) is then recalculated to the required supplied/taken off power in the next 15-minute interval following the formula:

$$\sum_{t=901}^{1800} P_t = \left[\sum_{t=901}^{1800} P_{TARGET\,(DOD)t} - \sum_{t=901}^{1800} P_{TARGET\,(ODOB)t}\right] + \left[\sum_{t=901}^{1800} P_{AB\,(ODOB)t} + \sum_{t=901}^{1800} P_{AB\,(DOD)t}\right] \tag{13}$$

Table 4 15-minute levels of fluctuations and *SoC* balancing

t900[s]	Pdod [MW/MWh]	Podob [MW/MWh]	Active framework [AF]	Frame of charge [FOC]	Frame of discharge [FOD]
1	238,728	-11,558	115	1,975	0,000
2	35,782	-58,905	470	0,098	0,000
3	39,125	-71,914	473	0,139	0,000
4	11,032	-56,262	590	0,153	0,000
5	208,608	-6,415	184	0,000	-0,761
6	7,837	-94,192	454	0,380	0,000
7	23,923	-61,626	492	0,153	0,000
8	6,834	-75,179	494	0,277	0,000
9	1,303	-70,475	566	0,244	0,000
10	46,875	-29,109	524	0,000	-0,014
11	139,667	-9,605	286	0,000	-0,443
12	23,119	-40,216	604	0,057	0,000
13	0,000	-399,549	0	0,000	0,000
14	0,000	-216,885	233	1,862	0,000
15	0,000	-302,526	47	20,241	0,000
16	65,911	-105,803	202	0,395	0,000
17	130,516	-85,521	231	0,000	-0,195
18	202,416	-0,145	157	0,000	-1,197
19	124,068	-0,579	376	0,000	-0,328
20	157,682	-22,522	294	0,000	-0,368
21	13,627	-226,380	255	1,725	0,000
22	37,063	-14,023	629	0,000	-0,037
23	195,908	0,000	136	0,000	-1,308
24	100,528	-13,956	407	0,000	-0,213
25	38,458	-147,472	291	0,834	0,000
26	60,111	-15,710	521	0,000	-0,085
27	49,398	-58,698	439	0,058	0,000
28	73,034	-4,063	535	0,000	-0,129
29	54,066	-90,605	388	0,237	0,000
30	125,113	-1,737	363	0,000	-0,324
31	70,976	-9,610	545	0,000	-0,113
32	9,737	-53,742	559	0,157	0,000
33	110,275	-16,871	411	0,000	-0,171
34	11,210	-89,858	444	0,354	0,000
35	33,745	-31,756	542	0,000	-0,004
36	4,060	-62,227	546	0,213	0,000
37	43,156	-41,930	533	0,000	0,000
38	196,842	0,000	202	0,000	-0,974
39	117,490	-7,851	335	0,000	-0,327
40	21,744	-101,450	350	0,455	0,000
41	150,110	-25,222	361	0,000	-0,346
42	15,067	-42,037	633	0,085	0,000
43	183,097	-2,171	247	0,000	-0,599
44	15,410	-29,023	679	0,040	0,000
45	153,401	-12,233	284	0,000	-0,441
46	51,476	-18,658	565	0,000	-0,058
47	56,653	-64,672	357	0,079	0,000
48	0,000	-76,305	514	0,297	0,000
49	236,796	-12,319	64	0,000	-1,420
50	105,927	-16,878	457	0,000	-0,195
51	142,786	-6,249	322	0,000	-0,342
52	31,563	-77,561	460	0,200	0,000
53	20,074	-70,137	496	0,202	0,000
54	11,780	-127,226	326	0,814	0,000
55	49,032	-45,411	504	0,000	-0,007
56	13,232	-59,329	544	0,169	0,000
57	6,184	-113,492	394	0,609	0,000
58	34,997	-44,717	502	0,039	0,000
59	118,540	0,000	376	0,000	-0,302
60	158,140	-11,724	228	0,000	-0,446
61	12,352	-143,248	262	0,999	0,000
62	62,266	-6,453	629	0,000	-0,089
63	16,023	-61,409	508	0,200	0,000
64	103,700	-14,776	339	0,000	-0,163
65	4,516	-69,541	581	0,224	0,000
66	94,801	-15,853	391	0,000	-0,093
67	120,890	-25,800	297	0,000	-0,291
68	94,430	-44,268	323	0,000	-0,155
69	0,145	-192,440	362	1,062	0,000
70	213,816	0,000	83	0,000	0,000
71	284,932	0,000	5	0,000	-56,986
72	283,082	0,000	63	0,000	-4,493
73	43,575	-73,230	375	0,158	0,000
74	0,000	-298,029	128	4,962	0,000
75	0,000	-378,539	3	459,106	0,000
76	0,000	-368,766	32	23,048	0,000
77	307,697	-13,200	81	0,000	-3,636
78	13,474	-242,817	90	5,097	0,000
79	10,097	-106,658	506	0,382	0,000
80	0,000	-198,526	144	3,717	0,000
81	34,714	-115,726	385	0,421	0,000
82	10,455	-123,388	412	0,548	0,000
83	197,578	0,000	323	0,000	-0,461
84	0,000	-55,358	545	0,203	0,000
85	113,161	-70,810	284	0,000	0,000
86	0,000	-179,585	168	2,138	0,000
87	16,222	-164,862	304	0,978	0,000
88	0,000	-514,811	0	0,000	0,000
89	291,561	-83,676	51	0,000	-4,076
90	44,074	-150,222	204	1,041	0,000
91	0,000	-331,766	0	0,000	0,000
92	0,000	-577,420	0	0,000	0,000
93	46,469	-198,994	140	2,179	0,000
94	0,000	-363,900	41	23,013	0,000
95	0,000	-173,175	246	1,408	0,000
96	1,303	-100,920	477	0,418	0,000

7. RESULTS

From this analysis, we can see that the energy storage in battery systems is an effective way how to provide primary control power. Introduction in non – sensibility frequency zone and *SoC* regular circuit stores, the batteries within a reasonable range of charging level and minimalizes the impact on battery life. The estimated loss of battery life in 50 % capacity is during increasing in non – sensibility zone from $\eta < \pm$ 10 mHz to $\eta < \pm$ 20 mHz it increased from 10,9 the year to 15,8 of the year. The number of the cycles in non – sensibility zone from 57,44% to 77,28% by $\eta < \pm$ 20 mHz. It is necessary to establish algorithms in order to keep the system stability so that the capacity losses are as low as possible. At the same time, it is essential not to forget about the losses caused by self-discharging of the batteries (these are the consequence of efficiency of particular charging/discharging cycles). BESS will undoubtedly become popular thanks to the future reduction in costs resulting from expanding employment and mass production of components such as batteries and power elements. In our next paper, we tend to evaluate the algorithms of accumulation equilibrium state balancing in detail; consequently, in case of capacity loss and further support needed, such as voltage stability and accumulation of renewable sources energy.

8. CONCLUSIONS

In our analysis we did not put the attention on economic benefits quantification of BESS devices, but with predicted prices decreasing for the installed capacity unit of electricity and density increasing of electricity, which is stored in the battery system, in next the years we expect wider BESS deployment systems in distributional networks.

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