Investigation on power quality assessment in data centre

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ABSTRACT

The Data Centre (DC) is used to store the database for customer's related services like banking, IT sectors and share marketing etc. In order to accomplish the scheduled tasks and manipulate the bushiness hours effectively Data Centre (DC) needs uninterrupted power supply (UPS). The major equipments of DC are UPS, chiller or PAC, Precision Air Handling Unit (PAHU) or Air Handling Unit (AHU) etc. While these equipments come into operation they are adversely affected with power quality problem particularly from voltage sag. If the voltage magnitude during the voltage sag exceeds the low voltage tolerance limits, the sensing device in the UPS system senses the input voltage with respect to tolerance limit and it turns ON the battery mode. Under battery mode condition the Data Centre (DC) gets rated voltage continuously and work is carried out without power interruption. When incoming supply voltage is resumed back to its rated value UPS systems turns off the battery mode and turns on the normal supply mode. This is how Data Centre (DC) is effectively compensated by UPS. But in the case of chiller PQ problem caused by voltage sag is not compensated. If the voltage sag events continue, the under voltage relay trips the power input and data centre equipments get turn off. Hence the room temperatures of DC will ubrubtly increase and causing data center failure. In order to figure out the problems in data centre caused by power quality i.e. voltage sag, the PQ assessment was carried out at DIGSILENT power factory in Bengaluru, India connected with 11 kV Ring Main Unit (RMU) for four days between 22/9/2017 to 25/9/2017. About 36 voltage sag events and 4 interruptions were captured and the highest temperature inside the DC hall was also recorded. This paper discuses the techno-economical location for installing the DSTATCOM to enhance the power quality during voltage sag event for the data centre (DC). Dranetz Power Guide 4400 Power Quality Analyzer (PQA) has been used for PQ assessment. and carried out at DIGSILENT power factory.

*Keywords— Voltage sag, FACTS, DSTATCOM, Data center, chiller, UPS*

1. INTRODUCTION

The Data Centre (DC) plays a predominant role to store and retrieve the data for various customers related services like banking, railways, transport bus IT/ITES, marketing and medical operating theatre etc. As per TIA standard Data centre (DC) is classified into four categories based on supply availability and redundancy. These are Tier 1, Tier 2, Tier 3 and Tier 4 DCs. Uninterrupted power supply for DC is provided by UPS system with battery backup. In order for providing the optimal cooling and maintain the temperature, humidity and air quality to very high accuracy relative to the external temperature, the Data Centre (DC) is connected by chillers or Precision Air Conditioning (PAC) and Air Handling Unit (AHU). Due to power quality problem the data centre (DC) is mainly affected by harmonics, voltage sag, power interruption etc. IEEE standard 1159 – 2009, has classified the PQ problems into the following categories. 1) Short duration voltage variations (voltage sag, swell and interruption), 2) long duration voltage variations (under voltage, over voltage and interruption) 3) waveform distortion 4) transients (impulsive and oscillatory) 5) imbalance (voltage and current) 6) voltage fluctuation and 7) power frequency variations. Voltage sag is one of the PQ problem classified under short duration voltage variation causing either of the following reasons 1) switching ON large motors, 2) switching ON large loads, 3) energization of large transformers, 4) power system faults. The IEEE standard 1159 – 2009, describes the reduction in voltage magnitude between 0.9 p.u and 0.1 p.u from the nominal voltage for the time duration between 0.5 cycles to 1 minute is called as voltage sag. Due to voltage sag, the DC equipments receive low voltage magnitude below the nominal voltage. All the equipments have the upper and lower input voltage tolerance bandwidth for smooth operation. If the voltage magnitude during the voltage sag exceeds the voltage tolerance bandwidth of the equipments, electric motor would stall and its performance gets reduced, the UPS system senses the input voltage out of tolerance limit and turns ON to battery mode while the chiller and PAHU system senses under voltage eventually would get tripped from supply. Once the voltage is resumed back to nominal voltage, UPS system resumes back to rectifier or main mode. After a short span of time interval the cooling system such as chillers and PAHUs will also get turned ON while incoming voltage resumed back to its nominal value. But the DC equipments may take up at least 30 minutes to achieve the cooling and stabilize the temperature profile inside the DC hall. Under this condition the DC room temperature increases and the computing and networking equipment get overheated due to which the performance of the DC which is used for the purpose of collecting, storing, processing, distributing or allowing access

to large amounts of data would get affected. In order to ascertain the performance of DC equipment that is particularly affected by voltage sag, here power quality (PQ) assessment was carried out for a data centre (DC) located in Bengaluru, India connected at 11 kV Ring Main Unit (RMU) for the duration of four days between 22/9/2017 to 25/9/2017. During the assessment period 36 voltage sag events and 4 interruption events were identified and higher temperature prevailing inside the DC hall also was recorded. Generally, the PQ problems can be mitigated at either from customer premises or utility side or both customer premises as well as utility side. Mitigating the PQ problem at customer premises is called as load conditioning or load side compensation and mitigating PQ problem at utility side is called as line conditioning or line compensation. FACTS devices or custom power devices are providing the solutions to various power quality problems in the grid as well as end user. To alleviate this PQ problem one of the FACTS devices DSTATCOM is used. DSTATCM provides better solution for voltage sag problem and enhances the power quality by injecting or observing reactive power into the distribution system.

2. OVERVIEW OF DATA CENTER
To analyze the voltage sag event a Single Line Diagram (SLD) electrical distribution system is taken in to account as shown in figure 1. From this distribution system Data Centre (DC) receives the power input from 11 kV RMU with the sanctioned demand of 6 MVA. Main High-Tension Panel (MHTP) 1 receives the supply from RMU.
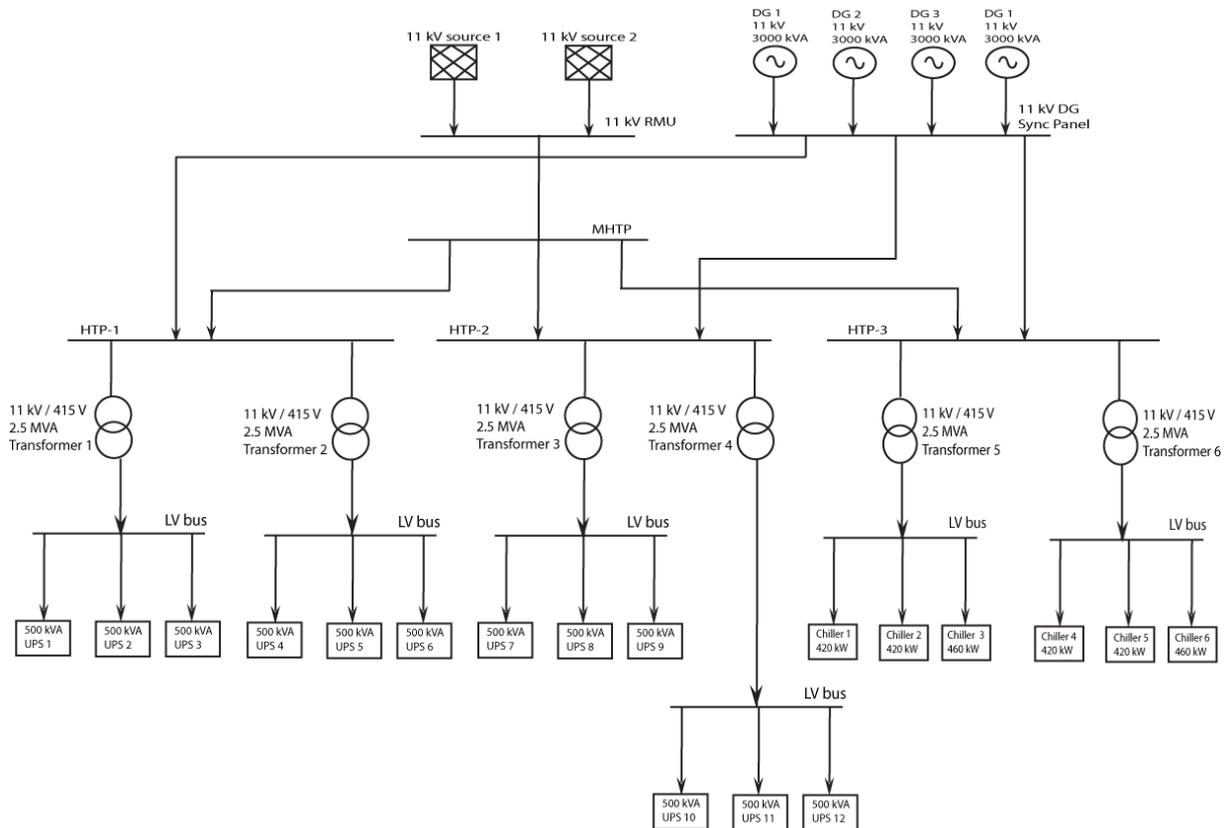
Fig. 1: Single Line Diagram

2.1 Power Quality Assessment for DC at 11 kV RMU
To carry out the PQ assessment at DIGSILENT power factory in Bengaluru, India connected with 11 kV RMU, Dranetz Power Guide 4400 Power Quality Analyzer (PQA) is used. As per IEC 61000-4-30 PQA is classified as class "A" meter. The summary of voltage sag events based on dates, time duration and voltage profile per unit are listed in table 1.

Table 1: Summary of voltage sag event

Type of event	Event No	Date	Time	Duration (ms)	Voltage					
					R - Y (V)	R - Y (p.u)	Y - B (V)	Y - B (p.u)	B - R (V)	B - R (p.u)
Voltage sag	1	22-09-2017	11:16:26	194.1	9835	0.89	9256	0.84	9880	0.9
Voltage sag	2	22-09-2017	12:45:29	132.2	10014	0.91	10519	0.96	9812	0.89
Voltage sag	3	22-09-2017	12:54:23	216.8	10001	0.91	10016	0.91	9256	0.84
Voltage sag	4	22-09-2017	13:27:31	96.7	10448	0.95	9876	0.9	10219	0.93
Voltage sag	5	23-09-2017	10:49:54	360.7	9486	0.86	9471	0.86	9645	0.88
Voltage sag	6	23-09-2017	12:40:58	480.2	9616	0.87	9675	0.88	9618	0.87
Voltage sag	7	23-09-2017	12:46:48	83.1	9551	0.87	9646	0.88	9525	0.87
Voltage sag	8	23-09-2017	14:07:52	101.7	9491	0.86	9512	0.86	9429	0.86
Voltage sag	9	23-09-2017	14:37:51	120.1	9484	0.86	10001	0.91	10206	0.93
Voltage sag	10	23-09-2017	16:17:01	100.1	2788	0.25	2475	0.23	2935	0.27
Voltage sag	11	23-09-2017	17:36:26	191.2	9585	0.87	9918	0.9	10266	0.93
Voltage sag	12	24-09-2017	09:40:19	116.4	9511	0.86	10066	0.92	9998	0.91

Type of event	Event No	Date	Time	Duration (ms)	Voltage					
					R - Y (V)	R - Y (p.u)	Y - B (V)	Y - B (p.u)	B - R (V)	B - R (p.u)
Voltage sag	13	24-09-2017	13:37:14	100.2	9387	0.85	10025	0.91	9933	0.9
Voltage sag	14	24-09-2017	13:52:55	174.8	9471	0.86	10358	0.94	10166	0.92
Voltage sag	15	24-09-2017	14:01:05	288.9	9661	0.88	9716	0.88	9564	0.87
Voltage sag	16	24-09-2017	14:24:17	200.7	9639	0.88	9964	0.91	9781	0.89
Voltage sag	17	24-09-2017	15:30:19	102.3	9687	0.88	8820	0.8	9796	0.89
Voltage sag	18	24-09-2017	16:08:04	104.1	10036	0.91	9771	0.89	10153	0.92
Voltage sag	19	24-09-2017	17:34:29	136.2	10003	0.91	9513	0.86	9993	0.91
Voltage sag	20	25-09-2017	02:16:42	90.2	9525	0.87	9801	0.89	9565	0.87
Voltage sag	21	25-09-2017	03:07:51	261.3	9394	0.85	9522	0.87	9344	0.85
Voltage sag	23	25-09-2017	03:49:25	102.1	9683	0.88	9817	0.89	9756	0.89
Voltage sag	24	25-09-2017	03:49:45	114.6	9702	0.88	9811	0.89	9754	0.89
Voltage sag	25	25-09-2017	03:52:34	94.5	9682	0.88	9792	0.89	9728	0.88
Voltage sag	26	25-09-2017	06:46:48	127.9	9162	0.83	9236	0.84	9245	0.84
Voltage sag	27	25-09-2017	08:17:02	174.2	9915	0.9	9384	0.85	9831	0.89
Voltage sag	28	25-09-2017	08:18:16	222.7	8811	0.8	9754	0.89	9574	0.87
Voltage sag	29	25-09-2017	08:36:16	203.1	10049	0.91	9801	0.89	9605	0.87
Voltage sag	30	25-09-2017	09:02:50	108.8	8667	0.79	9557	0.87	8926	0.81
Voltage sag	31	25-09-2017	09:36:53	344.4	9061	0.82	9911	0.9	9363	0.85
Voltage sag	32	25-09-2017	09:42:06	108.6	10269	0.93	9619	0.87	9739	0.89
Voltage sag	33	25-09-2017	09:52:45	157.3	9181	0.83	9018	0.82	8938	0.81
Voltage sag	34	25-09-2017	10:46:46	266.9	9267	0.84	9920	0.9	9414	0.86
Voltage sag	35	25-09-2017	10:54:37	322.1	9144	0.83	9641	0.88	9841	0.89
Voltage sag	36	25-09-2017	11:12:15	346.7	9589	0.87	10082	0.92	9562	0.87

From table 1 the voltage sag events around 36 are recorded. During the voltage sag events (worst), minimum voltage recorded in R-Y phase is 0.25 p.u, Y-B phase is 0.23 p.u and B-R phase is 0.27 p.u for the time duration of 120.1 ms. The voltage waveform and voltage in RMS during the voltage event is shown in figure 2 and figure 3 respectively.
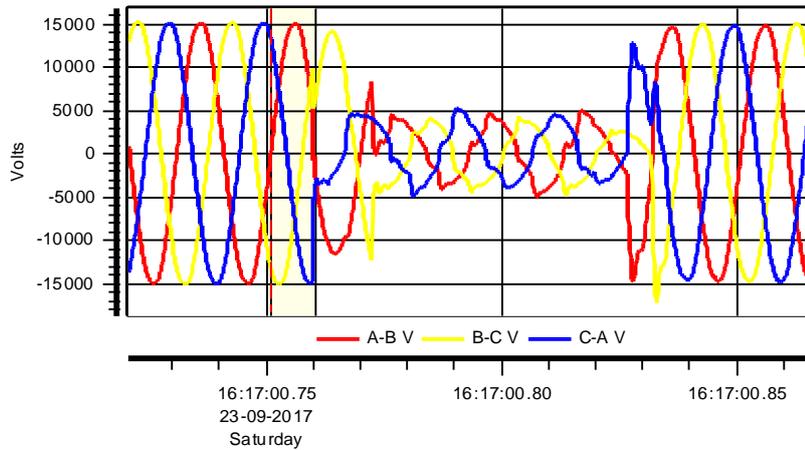

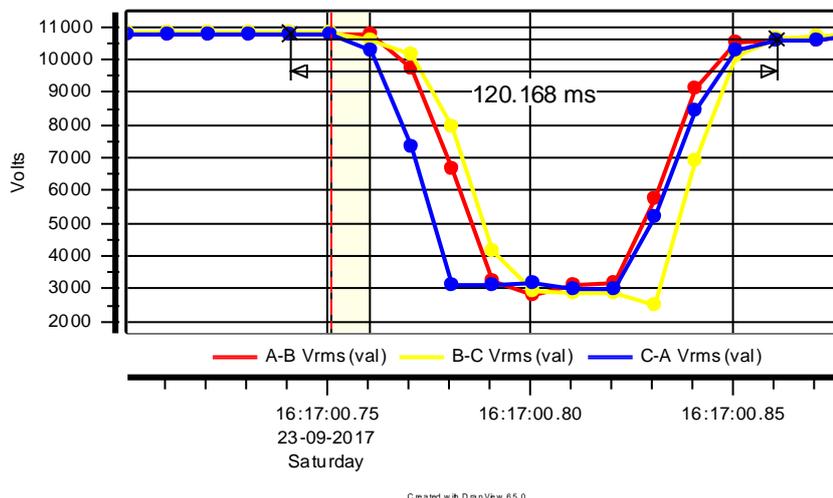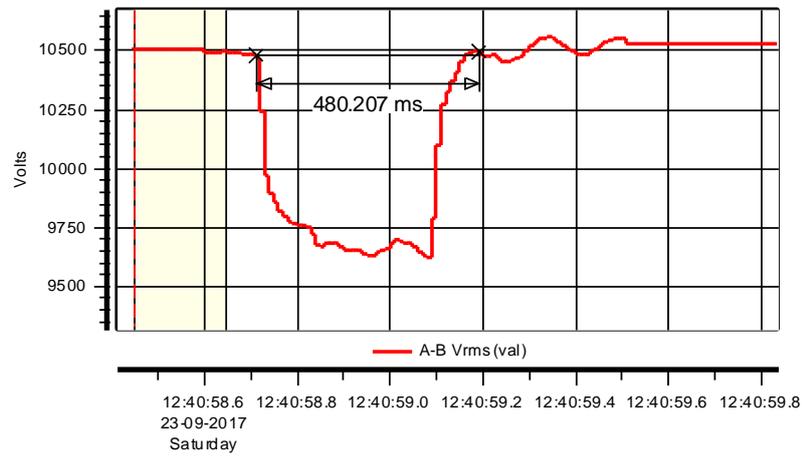**Fig. 2: Voltage waveform caused by the voltage sag event**

Fig. 3: Voltage in RMS during the voltage event

From the recorded voltage sag events the minimum duration is found as 83.1 ms and maximum duration is 480.2 ms. Figure 4 shows the voltage sag in R-Y phase for the time duration of 480.2 ms.

**Fig. 4: Voltage sag event in R-Y phase**

The minimum time for the occurrences of two voltage sag events is recorded as 20.7 seconds which is shown in figure 5.
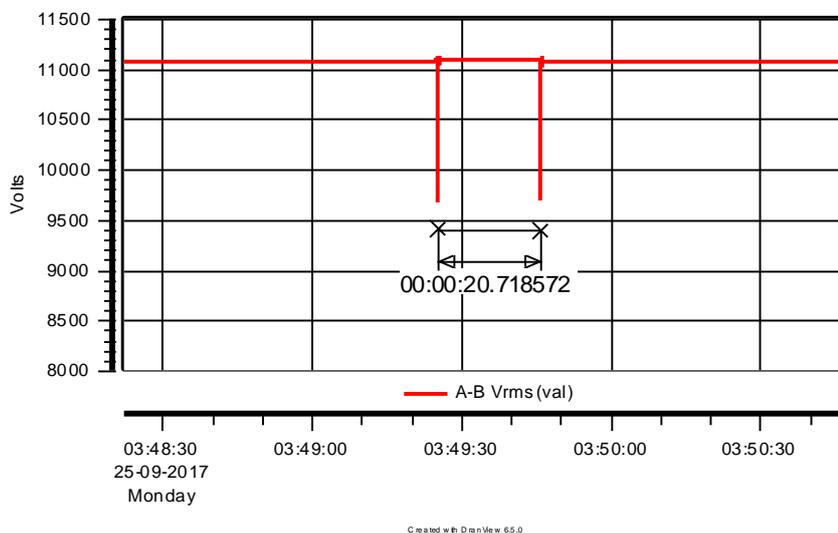
Fig. 5: Minimum time for the occurrences of two voltage sag events

3. ROLE OF FACTS DEVICES IN POWER QUALITY AUGMENTATION

FACTS devices are the combination of both passive components (R, L, and C) and active components (power semiconductor devices particularly voltage source inverter) where the passive components are controlled by active components. Based on type of connection, FACTS devices are generally classified into three categories namely series compensation, shunt compensation and hybrid compensation. Here DSTATCOM is used to improve the voltage regulation, mitigate the harmonic distortion produced by loads into the system, load balancing, and Power Factor (PF) improvement. It consists of coupling transformer; PWM control based voltage source converter is connected in parallel to the supply. A DSTATCOM is a controlled reactive power device that has the capability of supplying or absorbing the reactive power in the system. The concept of absorbing and injecting the reactive power accomplished by the DSTATCOM is shown in figure.
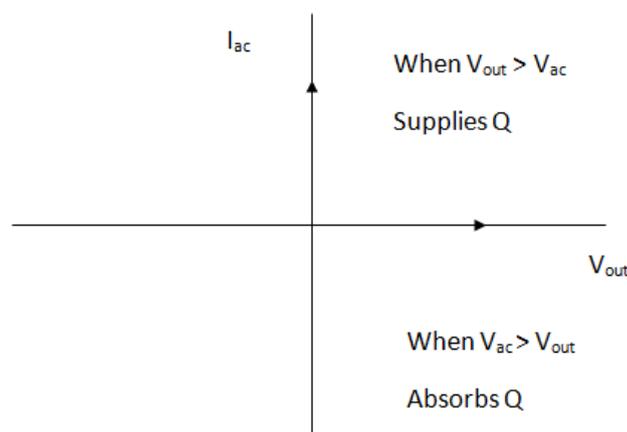
Fig. 6: Reactive power exchange of DSTATCOM

4. CONCLUSION

Voltage sag events are unavoidable PQ problem caused by system faults, Turn ON and turn OFF large motors, large loads, and energization of higher rating transformer etc. During the voltage sag events, voltage magnitude at the distribution end gets reduced below the nominal voltage and causes to trip the input supply of the load such as Data centre (DC) equipments like chillers Precision Air Handling Unit (PAHU) or Air Handling Unit (AHU) and other rotating loads etc. Followed by voltage sag the room temperature of the Data Centre (DC) crosses over its permissible limit and affects the performance and efficiency of the network system connected with Data Centre (DC). Hence DC becomes unstable until the DC equipments get rated voltage and maintains required cooling inside the DC hall. With help of power quality assessment under voltage sag events observed at the Diligent power factory, Bengaluru is practically studied and recorded. There are 36 voltage sag events recorded and tabulated. The worst voltage reduction during the sag event is lasted for 120.1 ms and voltage is reduced to 0.25 p.u in R-Y phase, 0.23 p.u in Y-B phase and 0.27 p.u in B-R phase. The minimum time for the occurrences of two voltage sag events has been identified as 20.7 seconds. Based on the PQ assessment recorded in DIGSILENT power factory here the FACTS device DSTATCOM is recommended to connect at the distribution end. By injecting the reactive power or observing the reactive power DSTACOM always maintains the voltage profile within the appreciable limit and enhances power quality (PQ) at the distribution end perfectly.

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