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Analysing the Impact of Air Conditioner on Power Quality of Low Voltage Distribution System

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Abstract:

The use of air conditioner is increasing along with global warming. The rise in air conditioner load is a concern for power distribution company as the voltage profile and harmonic distortion level in the distribution system is growing. Analysis of power quality parameters of air conditioner at various condition like outside temperature and number of occupants is becoming important. This paper describes the impact of air conditioner on low voltage distribution feeder of College of Science and Technology (CST), Phuentsholing. Practical experiment is carried out using power quality analyser to see the impact at CST campus. Model is developed in Dig-SILENT software and the result is compared. The result from both power quality analyser and Dig-SILENT software gave an alarming level of voltage drop and harmonics in the low voltage distribution system. Mitigation measures like installation of inverter type air conditioner, providing proper insulation, reducing the length of the conductor and use of reactive power compensator is found to reduce harmonics and improve voltage profile.

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Keywords **—Power quality, Air conditioner, Voltage drop, Harmonics, Inverter A/C**

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I. INTRODUCTION

With rising popularity of the air conditioner (A/C), it is important for operators to understand the types of load and its impact on the network operation. The continuous increase in the number of A/C load has the potential to cause problems in terms of power quality [1]. Space cooling consumes 13% of domestic energy in Bhutan [2].Consequently, A/C load is now a significant part of the summer peak demand in the Southern Bhutan. The main power quality problem due to A/C includes voltage drop and harmonics.Starting condition of the A/C have the major effect on the power quality due to voltage drops resulting from significant starting current generated by the compressor.

According to IPCC, the global temperature will rise from 2.5 to 10-degree Fahrenheit[3]. Therefore, temperature may rise every year leading to increase in the installation of A/C. A/C is one of the most energy consuming loads and the use of A/C is increasing in Phuentsholing. Therefore, it is necessary to analyse the impact of A/C and come up with mitigation measures.

II. METHODOLOGY

Among the data collected, College of Science and Technology (CST) low voltage distribution system has the largest number of A/C installed within Phuentsholing town. Total connected load is collected and calculated by taking the load factor into consideration. The network is modelled in DigSILENT software.Load flow study wascarried out with and without A/C load.

Power quality analyzer (PQA) is used to measure the voltage, current, power factor and harmonics of fan and A/C in order to see its impact on power quality on the distribution systems. The power quality issues such as harmonics and voltage drops are obtained with A/C loads and mitigation measures are provided.

III. ANALYSIS USING POWER QUALITY ANALYZER

III.I Power quality comparison between fan and A/C

Power quality of single A/C unit was compared with all the fans in the same room. Both the experiments were conducted at the same temperature of 25□ with two people inside the room.Current drawn, voltage drops and harmonic content were higher in case of A/C.

Another experiment was conducted to make the current drawn by fan (by increasing no. of fans) nearly equal to A/C and compared the other power quality parameters.

Table 1: Power quality parameters for single A/C unit and all fans in academic block

Parameters	A/C	FAN
Current (A)	7.3(MAX-35.9)	7.8
Voltage drop (%)	4.0(MAX-5)	2.0
THDV (%)	2.6 (MAX-2.76)	2.28
THDA (%)	36.092(MAX-64.47)	7.14

Though the current drawn by fan was increased to almost same value as that of steady state current of single A/C unit, the voltage drops and harmonic content was still higher for A/C as compared to that of all connected fans. For A/C, the transient event occurred at 200 secs after the starting of the experiment.

III.I.I Voltage drop

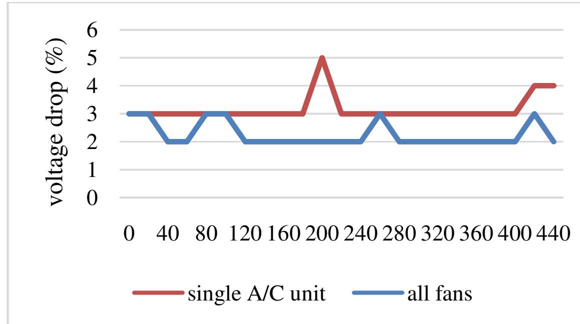

Fig.1: Voltage drop (%) in A/C and fans.

For A/C, the voltage drop was almost 3% but at the transient event, the voltage drop increased to 5%. Transient event didn't occur in fan and voltage drop was only 2 to 3 %.

III.I.II Current

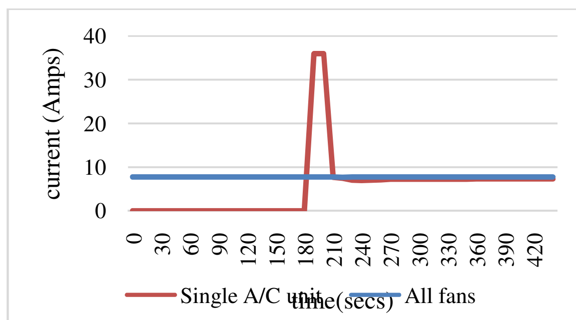

Fig.2: Current waveform of single A/C unit and all fans

For A/C, at the transient event there was a sharp rise in current to 35.9A for almost 10 sec and then the current decreased to almost 7.3A during steady state operation. Since there was no transient event in fan, the current drawn was almost equal from starting till the end of the experiment i.e. between 7.7A to 7.8A.

III.I.III Harmonics

Both THD of voltage and current for single A/C was higher than that ofall fans connected.

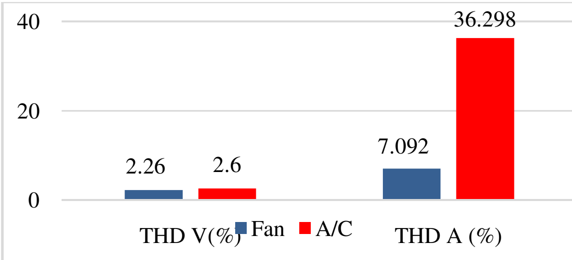

Fig.3: Harmonic content of A/C and fans.

III.II Analysis from the observation

From the above experiments, it was found out that transient events occur only in case of A/C units. Transient event occurs due to the starting of the compressor. During the starting of compressor, the A/C draws high current i.e. 5 to 8 times the normal current [4].During these transient events both the voltage drop and current drawn is maximum.

III.III All A/C units connected

In the experiment, impact on power quality parameters due to all A/C units connected in the academic block was measured.

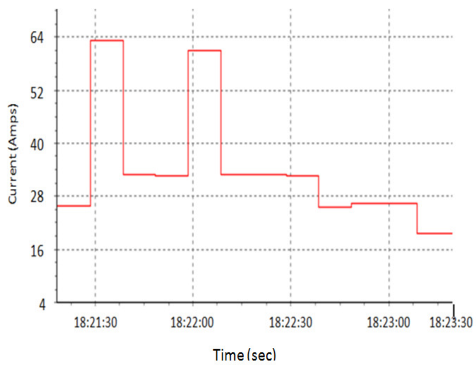

Fig.4: Current waveform for all A/C connected.

Compressor of different A/C was ON at different time at which the current took a sharp rise for a short period of time due to starting current. The starting current and steady state current operation of different A/C is at different time.

The voltage drop was 6% which is above the permissible limit when the starting current was drawn.

III.IV Analysis at different temperature.

In theexperiment which was conducted in the same classroom, the impact of difference in the temperature on the performance of the A/C unit was measured. The number of people inside the room was kept constant i.e. 2 numbers.

The current waveform for both A/C units when outside temperature was 30.7□ is shown below.

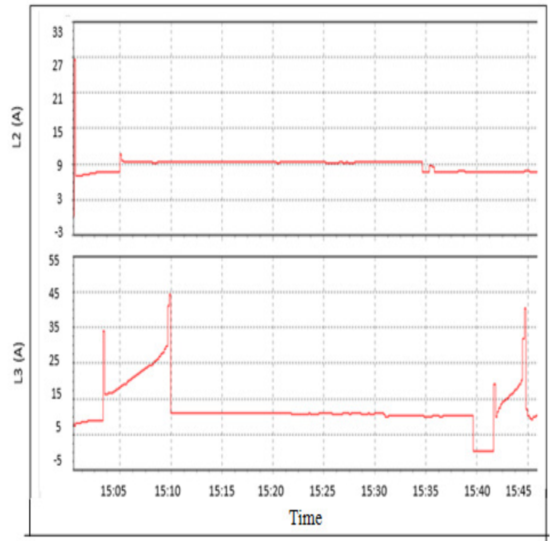

Fig.5: Current waveform for A/C in line 2 and line 3 at 30.7□

The current waveform for both A/C units when outside temperature was 26.6□ is shown below.

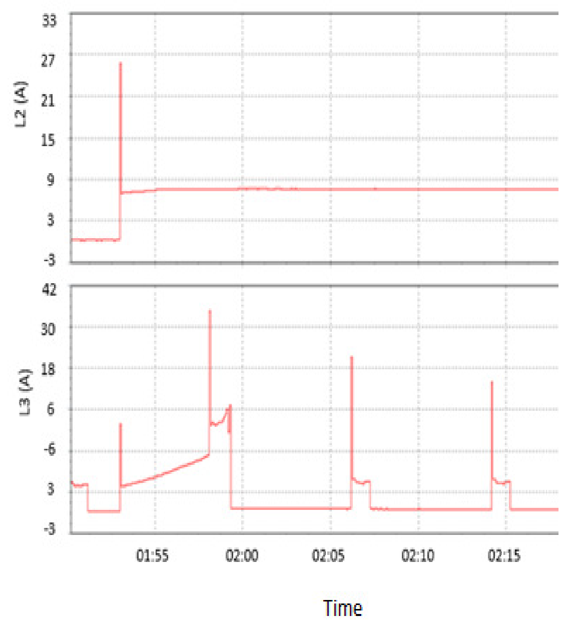

Fig.6: Current waveform for A/C in line 2 and line 3 at 26.6□

At low temperatureoutside (26.6□), compressor of A/C unit connected in line 1 was ON only after 3 minutes unlike at high temperature (30.7□). The average steady state current drawn by the A/C unit was 7.05A which is less than the current drawn at high temperature (8.53A).

For the A/C unit connected to line 2, the compressor is turned ON and stays in the steady state mode only for a short period of time. The fan mode works for a longer period of time drawing a current of 1.1A. The average current drawn by the A/C unit was 4.25A which is very less than the current drawn at high temperature (11.85A).

At lower temperature the compressor of second A/C unit is not required much because the compressor of first A/C itself can cool the room for longer period of time.

III.IV.I Current and power.

Table 2: Current and power consumed at different temperature.

	Outside temp= 30.7˚C		Outside temp= 26.6˚C	
Parameters	Line 2	Line 3	Line 2	Line 3
Current(A)	8.52	11.86	7.05	4.25
Power consumed(W)	1849	2628	1431	827
Total power consumed(W)	4477		2258	

The total current and power consumed at 30.7□ is higher than the power consumed at 26.6□.

III.IV.II Harmonic

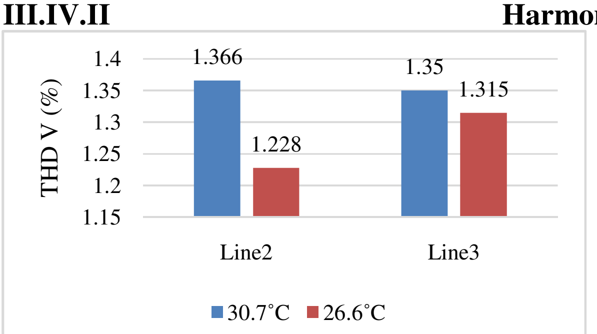

Fig.7: THD voltage at different temperature.

THD for voltage was high at higher temperature compared to lower temperature

III.V Analysis with increase in the number of occupants in the room

Table 3: Current and power consumed with different number of occupants

Temperature=26.6˚C				
	No. of occupants =2		No. of occupants =11	
Parameters	Line 2	Line 3	Line 2	Line 3
Current(A)	7.05	4.25	7.6	3.3
Power consumed(W)	1431	827	1658.4	623.2
Total power consumed(W)	2258		2281.6	

At constant temperature, total power consumed by A/C units with a greater number of occupants is higher compared to that with a smaller number of occupants.

III.V.I Theoretical calculation for the size of A/C

Table 4: Parameters for different room

Parameters.	**CR8**	**CR11**	**CR12**
Area (square feet)	1472	883.5	914.8
No. of A/C	4	2	2
Total ton of A/C (at present)	6	3	3
Total ton required.	7.9	4.95	5.022

Cooling capacity of different classroom was calculated using BTU calculation standard. At least one additional A/C of 1.5 Ton was required in each room. If the number of A/C installed is increased, then the impact will also increase. In order to reduce the impacts, mitigation measures are provided.

IV. MITIGATION MEASURES

IV.I Replacement of 1.5 Ton A/C with 1 Ton A/C

Even though the cooling capacity of 1.5 Ton A/C is more, it consumes more power compared to 1 Ton A/C. Under-sized A/C not only lowers the temperature inside the house but it also lowers the humidity to a reasonable level.

IV.II Replacement of non-inverter A/C with inverter A/C

As shown in figure 3, in non-inverter A/C, the compressor of the A/C is turned ON and OFF depending on the temperature of the room. The starting current drawn is 35.9A while the average steady state current is 7.3A.

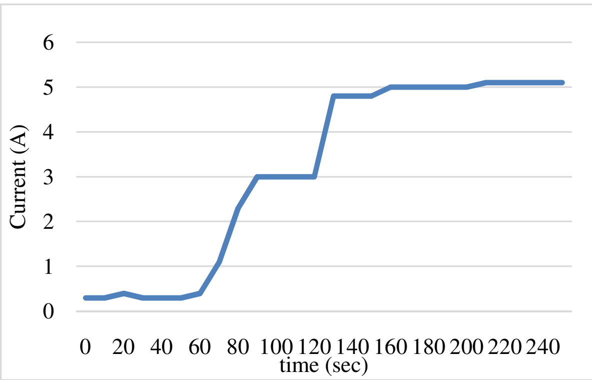

Fig.8: Current waveform in inverter A/C

In inverter A/C, there is no turning ON and OFF of compressor and the current drawn is uniform. The average current drawn is 5.2A.

In inverter A/C the compressor speed is controlledthus, consumes less current and less power [5]. Hence, installation of inverter A/C is required instead of non-inverter A/C.

V. ANALYSIS USING DIG-SILENT SOFTWARE

V.I Comparison of voltage drop (%) with and without A/C load

To see the overall impact of A/C on CST campus, CST network is modelled using Dig-SILENT software. Total connected load of CST is collected and calculated by taking the load factor into consideration.

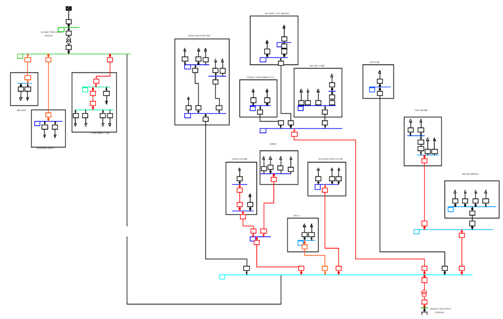

Fig.9: Load flow analysis of CST network

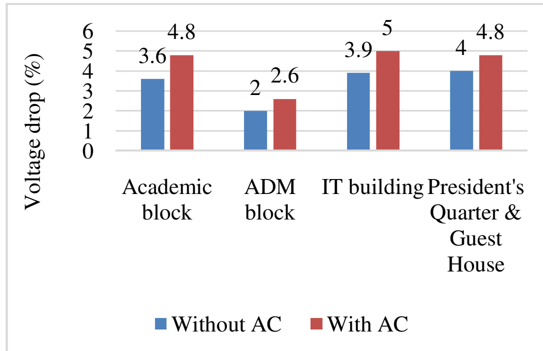

Fig.10: Voltage drop (%) with and without A/C load

The voltage drop (%) is less without A/C load compared to with A/C load.

V.II Mitigation measures using Dig-SILENT software

V.II.I Reducing the length of the conductor.

The actual length and reduced length of the conductor is found from the AutoCAD drawing of CST campus.

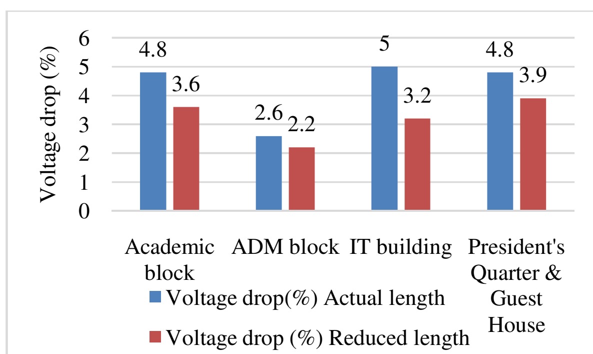

Fig.11: Voltage drop (%) with and without reduced length

Voltage drop (%) is more with the actual length and less with the reduced length.

V.II.II Using reactive power compensator (shunt capacitor).

The required rating for capacitor for each line to improve the bus voltage was obtained using power triangle.

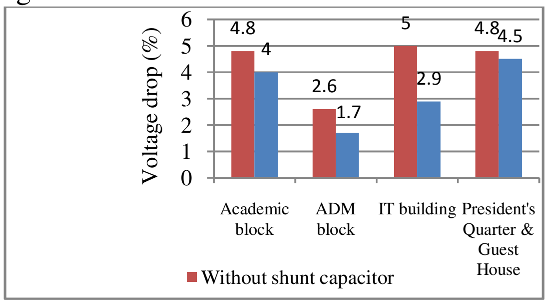

Fig.12: Voltage drop (%) with and without shunt capacitor.

Voltage drop (%) is reduced with the use of shunt capacitor.

VI. CONCLUSION

When the compressor is ON, the current drawn by A/C is 5 to 8 times the steady state current. As the amount of current drawn increases, voltage drop also increases. There is a huge voltage drop and harmonics due to A/C units compared to fan.

The current drawn and the power consumed by A/C changes with ambient temperature and load inside the room. If the outside temperature increases, then the compressor of the A/C will work harder to remove the heat from the room thereby drawing more current. Even with increase in the number of occupants inside the room, more heat is generated and the A/C works harder to cool the room.

From the calculation of cooling capacity, it was found out that at least one additional A/C unit of 1.5 Ton capacity is required in each room. With the increase in number of A/C, the power quality issues will also increase.

All the A/C units in academic block are non-inverter A/C which needs to be replaced by inverter A/C. The compressor speed is controlled with an inverter style A/C, which consume less current and power. Therefore, reducing the impact of power quality issues in future.

From the modeling in Dig-SILENT, the impact on the voltage drop with A/C load connected is found to be more than without A/C load. Reducing the length of the conductor or by using reactive power compensator can compensate the voltage drop caused by A/C load.

VII. RECOMMENDATIONS

Some other mitigation measures which can reduce voltage drop and harmonics are:

- Dynamic voltage restorer (DVR)
- Active harmonic filters
- Auto tap-changing transformers

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