Business case for loss reduction using Volt/VAR control in Indian grid

Initiative to address Power Quality issues

Manager (Loss Control Cell)
CESC Limited
Date: 22.02.2018

CESC Limited fact sheet

- 120 year old fully integrated utility – coal mining, Generation, Distribution
- 3 thermal plants – Aggregate capacity of 1125 MW at Budge Budge, Titagarh & Southern
- Covers 567 Sq. km of license area in Kolkata & Howrah serving 3.1million consumers, through 21866 Ckt. Km of T&D network

Key Highlights

- BBGS in top ten PLF list of CEA
- Migrating mindset from engineering company to service company
- Renewables – 27 MW solar power plant & 146 MW wind power plant, Rajasthan, Gujrat & Madhya Pradesh
- Primary focus – Customer Centricity – Boundary- less customer service
- Launched a bunch of e-services & presence in social media

Operating Performance

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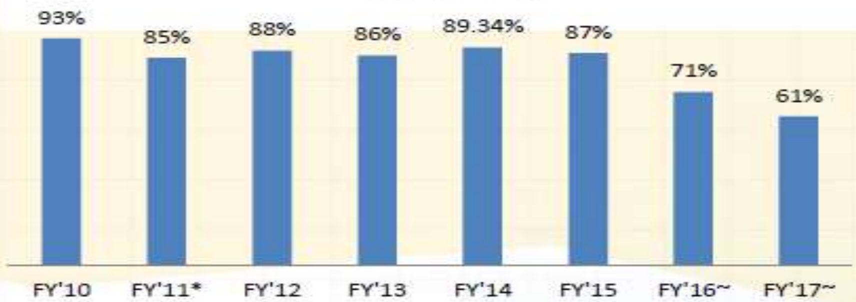
A. Sales (MU)

B. No. Of Consumers (Lakhs)

C. T&D Loss

From around 23% in 2001-02 now it is one of the best in the country

D. PLF%



* 250 MW BBGS Unit 3 fully added in FY11

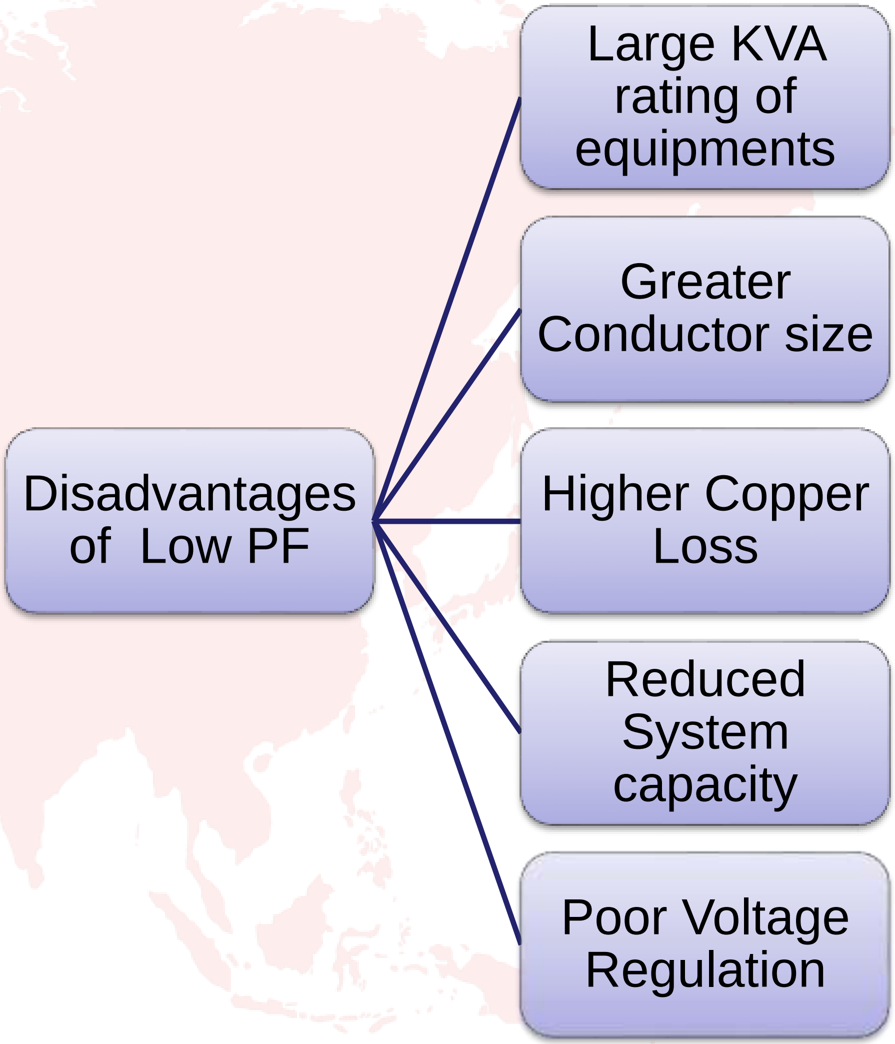
~ BBGS PLF is 82%.

PQ issues in CESC

VAR is required for:

* Connected Inductive Loads
* Ever growing Non linear loads

Result - Low Power factor / Voltage drop

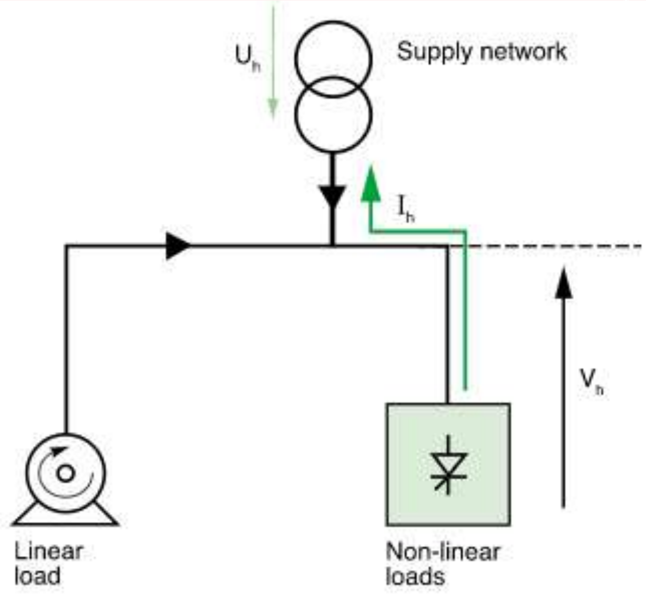


Impact of Harmonics

Harmonics are caused by:

- Connection of non-linear loads generating harmonic currents I_h
- Voltage distortion U_h present on the supply network due to non-linear loads outside of the considered circuit (incoming harmonic voltage).

For 69 KV or lesser voltage Individual voltage distortion (%) is limited to 3% and total voltage distortion THD (%) is limited to 1.0.(IEEE limitation)



Single line diagram of a bus bar (Generation of harmonics).

Initial Scenario & challenges

- Lack of availability of voltage profile data (11 KV feeders/ LV distribution)
- Lack of availability of PF data for Distribution transformers & LV consumers

Present scenario

- Distribution transformers are fitted with AMR
- Loading/Voltage profile/PF data is available for half hourly interval
- Browser based analytical tool developed for remote monitoring/data analysis

1500 Distribution transformers identified which operates under Low PF (Range – 0.69 to 0.9)

- ❑ Immediate action required for 550 DTRs (CAPEX allocated for FY 16-17)
- ❑ Remaining (FY 17-18)

APFC IS REQUIRED TO BE INSTALLED FOR VAR OPTIMIZATION

Harmonic analysis

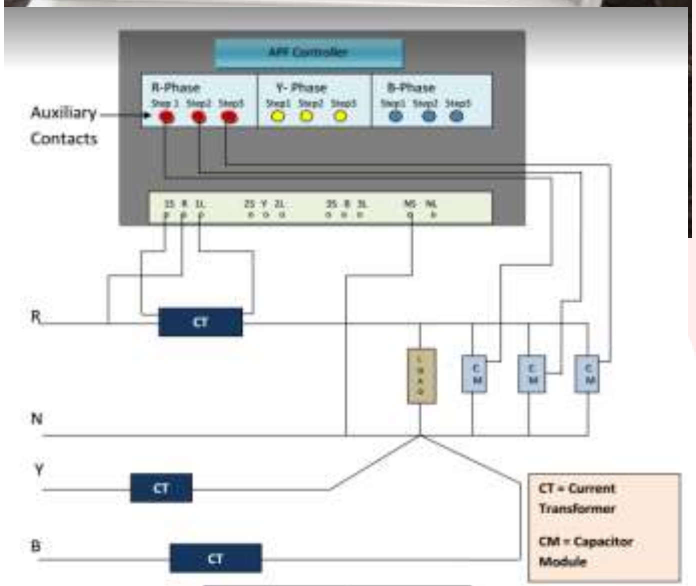
Harmonic plays important role in design of APFC Unit
Presence of harmonics reduced the shelf life of the capacitors
Reactors plays important role in harmonic suppression

Order of Harmonics	% THD in Voltage			Frequency(Hz)		
	R-Y	Y-B	B-R	R-Y	Y-B	B-R
1	1.4	1.1	0.7	50	50	50
2	1	1.1	0.7	100	100	100
3	0.8	1	0.8	150	150	150
4	0.8	1.2	0.8	200	200	200
5	1.1	1.4	0.8	250	250	250
6	1.3	1.5	0.8	300	300	300
7	1.4	0.9	0.7	350	350	350
8	1	0.8	0.8	400	400	400
9	0.9	1	0.9	450	450	450
10	0.9	0.9	0.9	500	500	500

Harmonic analysis carried out at the LV side of the Distribution Transformer

%THD of Ichapur O/T-1A

Design of APFC Unit



Components:

A. Controller

B. Capacitor Bank

C. Heavy Duty Contactor

D. Auxiliary Relay

E. Current Transformer (CT)

F. Circuit Breaker

G. Discharge Resistor

H. Enclosure Box

Conforming IS 16636:2017

Installation of APFC Unit

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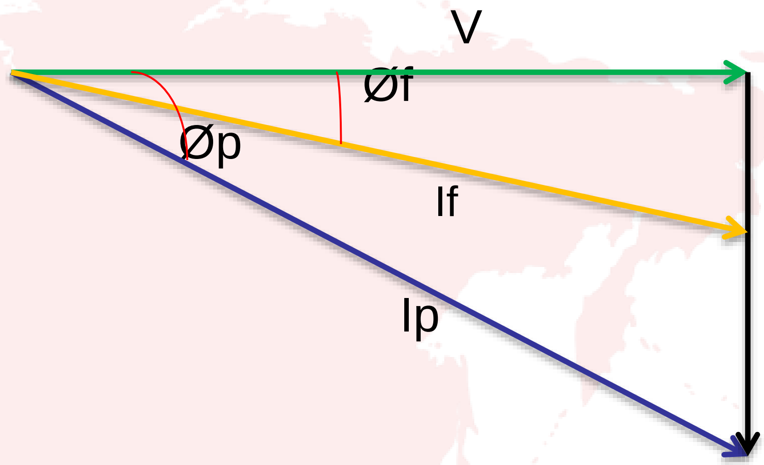
APFC Unit installed at Sealdanga (C) P/T



Cos Øp - Initial PF
Cos Øf – Final PF
Ip – Line current at initial PF
If – Line current at final PF
V- Phase voltage
Wp – $(Ip)^2 \times R$ [Watt loss]
Wf – $(If)^2 \times R$ [Watt loss]
R – Line resistance
V = Ip Cos Øp = If Cos Øf

% Loss Reduction = $[(Wp - Wf) / Wp] \times 100 = [1 - \{ (If)^2 / (Ip)^2 \}] \times 100$

$= [1 - \{ (\cos Øp)^2 / (\cos Øf)^2 \}] \times 100$

(KVA) initial = [(PF initial) / (PF final)] x (KVA final)

Business case from Pilot study

ASIA POWER QUALITY INITIATIVE

11KV HT feeder of Howrah (W) Distribution Station

Calculation of Loss reduction by PF improvement:

Average power factor of the HT feeder= cos [Inverse tan (KVARh / KWh)] = 0.69
System input for the month = 356762.5 units
If average PF improves to 0.98
% Loss reduction = [1 – (Old PF / Improved PF)^2] X 100 %
= [1 – (0.69 / 0.98)^2] X 100 %
= 50.43 %

Calculation of saved units:

Input units at the feeder = 356762.5 units
Technical Loss = 4.22%
% Loss reduction due to PF improvement = 50.43%
Units Saved / month = 0.5043 X 0.0422 X 356762.5= 7592 units
Units Saved/ Year = 91,109 units
Saving / Year (@ Rs. 4.50 / Unit): Rs (91109 X 4.5) = Rs. 409990/-

Calculation of Payback period:

Approximate cost of installing APFC at 6 DTs = Rs. 15, 00, 000/-
Payback period = 15, 00, 000 / 4,09,990 = **3.6 years**

Business case from Pilot study

KVA Capacity released due to PF improvement:

KVA old = Max. KVA = 1670.03 KVA
(KVA) new = [(Old PF) / (Improved PF)] x (KVA old)
= (0.69/0.98) x 1670.03
= 1175.837 KVA

KVA Released : 1670.03 – 1175.837 = 494.193 KVA (i.e. 29.59 %)

CAPEX Deferral for 1 KVA saving / Year = Rs. 3000/-

Gain due to KVA saving = Rs. 14,82,579/-

APFC installation outcome

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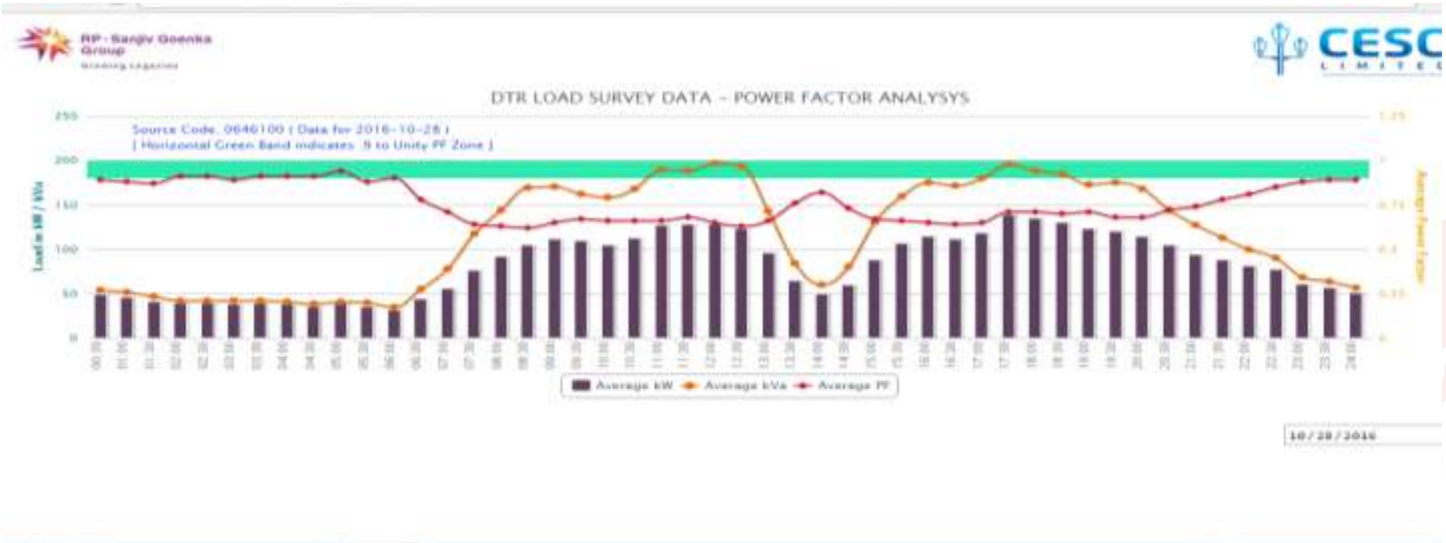
Sealdanga (C) P/T

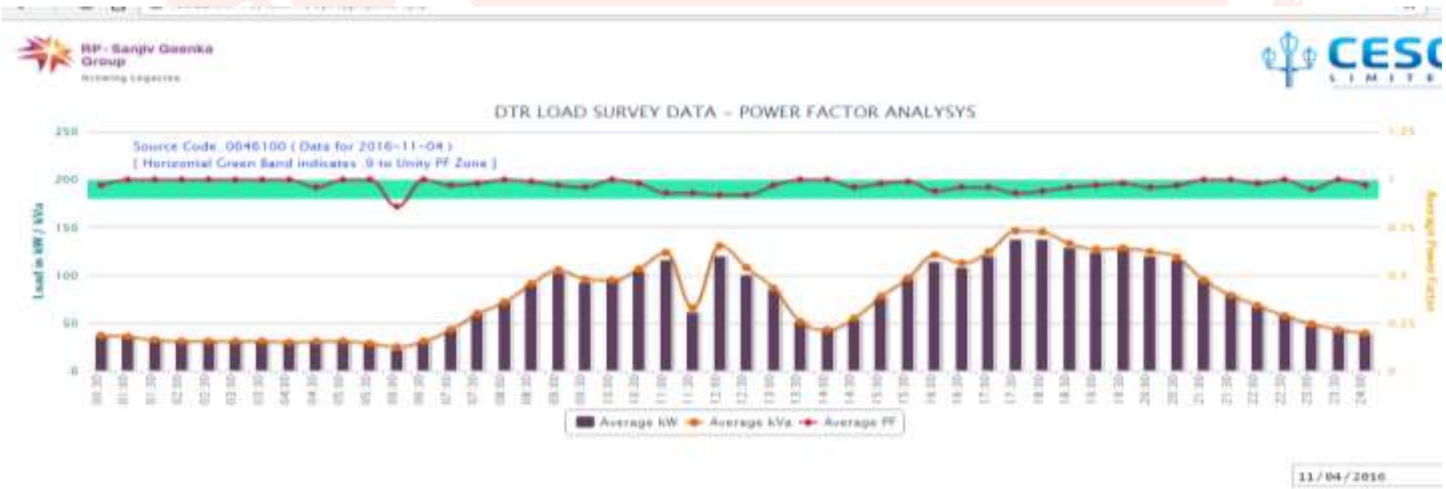
Date/Time of installation: 31.10.16 (12:45 hrs)

SEALDANGA (C) P/T (315 KVA) From : 28/10/2016 To : 07/11/2016 Power Factor 0.0 to 0.8 Close

(Values Highlighted are within Given Range / Value in Red is Min Value)

TIME / DATE	Phase	6.00	6.30	7.00	7.30	8.00	8.30	9.00	9.30	10.00	10.30	11.00	11.30	12.00	12.30	13.00	13.30	14.00	14.30	15.00	15.30	16.00	16.30	17.00	17.30	18.00	18.30	19.00	19.30	20.00	20.30	21.00	21.30
06-11-2016	3p-PF	.95	.96	.95	1	1	.98	.96	1	.98	1	.98	.98	.98	1	.97	1	.96	.96	.96	1	.93	1	.97	1	.94	1	.97	.97	1	.97	1	.97
05-11-2016	3p-PF	.94	.93	.97	1	.98	.96	.92	.93	.94	.92	.9	.87	.91	.93	.99	1	.97	.98	.98	.99	.93	.94	.97	1	.99	.99	1	.98	.98	1	.96	1
04-11-2016	3p-PF	.86	1	.97	.98	1	.99	.97	.96	1	.98	.93	.93	.92	.92	.97	1	1	.96	.98	.99	.94	.96	.96	.93	.94	.96	.97	.98	.96	.97	1	1
03-11-2016	3p-PF	.95	.97	.97	.98	.98	1	.99	1	.97	1	.96	.94	.98	.98	1	.96	1	.98	.99	.99	.96	.94	.96	.96	.95	.96	.99	.99	.98	.99	1	.98
02-11-2016	3p-PF	1	1	.97	.94	1	.98	.98	.98	1	.98	.99	.99	.99	.99	1	.98	1	.98	.96	1	.99	.99	.99	1	.99	.99	.99	1	.99	1	.98	.98
01-11-2016	3p-PF	.96	.96	.97	1	.97	.97	.97	1	.97	.93	1	.97	.97	1	.97	1	.92	1	.96	.97	1	.97	.97	1	.98	.98	1	1	.98	1	.98	.98
31-10-2016	3p-PF	.9	.96	.84	.81	.78	.73	.7	.69	.73	.66	.65	.65	.63	1	.75	.95	1	1	.96	1	.98	.98	.98	1	.99	.98	1	1	.97	1	.98	1
30-10-2016	3p-PF	.95	1	.91	.93	.89	.88	.82	.79	.77	.72	.77	.76	.77	.78	.75	.84	.9	.93	.89	.92	.88	.86	.81	.87	.89	.91	.89	.92	.9	.91	.93	.93
29-10-2016	3p-PF	.89	.72	.74	.68	.67	.68	.67	.66	.68	.69	.69	.66	.66	.66	.68	.76	.87	.83	.76	.72	.74	.7	.75	.8	.82	.84	.88	.89	.9	.9	.9	.92
28-10-2016	3p-PF	.9	.78	.71	.64	.63	.62	.65	.67	.66	.66	.66	.68	.65	.63	.66	.76	.82	.73	.67	.66	.65	.64	.65	.71	.71	.7	.71	.68	.68	.72	.74	.78


RP - Sanjiv Goenka Group
CESC
DTR LOAD SURVEY DATA - POWER FACTOR ANALYSYS
Source Code. 0646100 (Data for 2016-10-28)
[Horizontal Green Band indicates .9 to Unity PF Zone]
Load in kW / kVa
Average Power Factor
Average kW
Average kVa
Average PF
10/28/2016

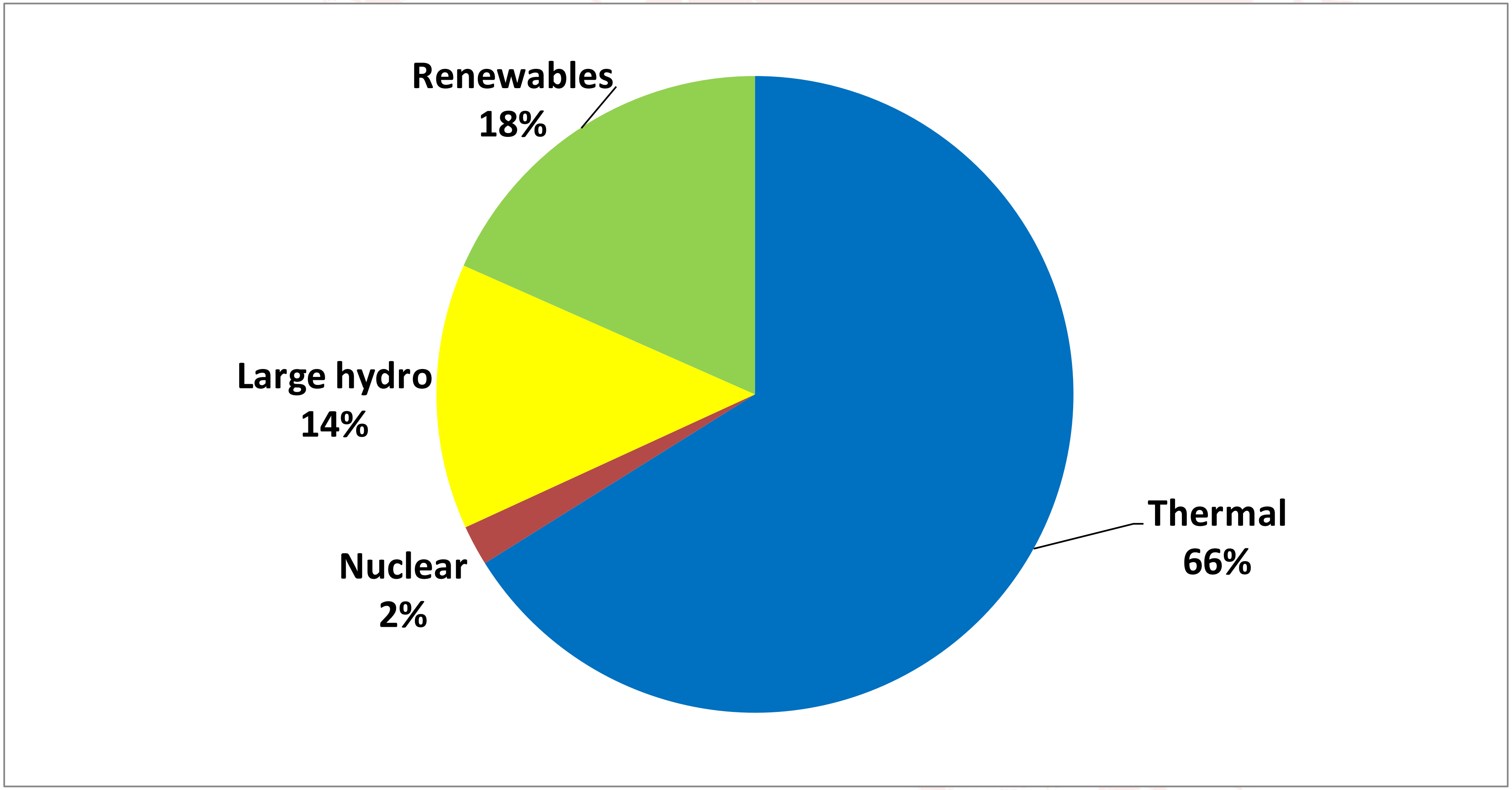

RP - Sanjiv Goenka Group
CESC
DTR LOAD SURVEY DATA - POWER FACTOR ANALYSYS
Source Code. 0646100 (Data for 2016-11-04)
[Horizontal Green Band indicates .9 to Unity PF Zone]
Load in kW / kVa
Average Power Factor
Average kW
Average kVa
Average PF
11/04/2016

Attributes	
DTR selection criteria for APFC installation	❑ DTR Loading > 50% of rated capacity ❑Duration > 20% ❑ PF range = PF>0.6 & PF < 0.9 ❑One time mapped with HT feeder as per electrical isolation based on available data
Execution model	❑ Site inspection –Joint inspection by CESC & vendor ❑Local issues (site objection etc.) – to be dealt by the concerned district ❑ Erection & commissioning by vendor ❑Required access to be provided by PLAC ❑Performance monitoring tool : LT – Shall be developed by TD in TD 24X7 HT – Shall be developed by Mains MIS
Installation practices	❑ Separate body earth to be provided ❑ Unit to be mounted on iron frame ❑70 sq.mm power cable to be connected with PB ❑Control cable to be terminated at CT secondary side located in the LV box of DTR
Probable vendors	❑ EPCOS ❑Thermotech ❑ABB ❑Schineider ❑Hi-Tech ❑OPG

Attributes	
AMC model	❑ Vendor will be responsible for maintenance, trouble shooting, fault repairing etc. (Preventive & breakdown maintenance for 5 yrs.)
Monitoring practices	❑Performance monitoring tool : LT – Available under DT meter-PF analysis APFC Unit in TD 24X7 HT – Shall be developed by Mains MIS
Installation Target	❑ FY 16-17 : 550 ❑FY 17-18 : 900
Process owner	❑ PLAC

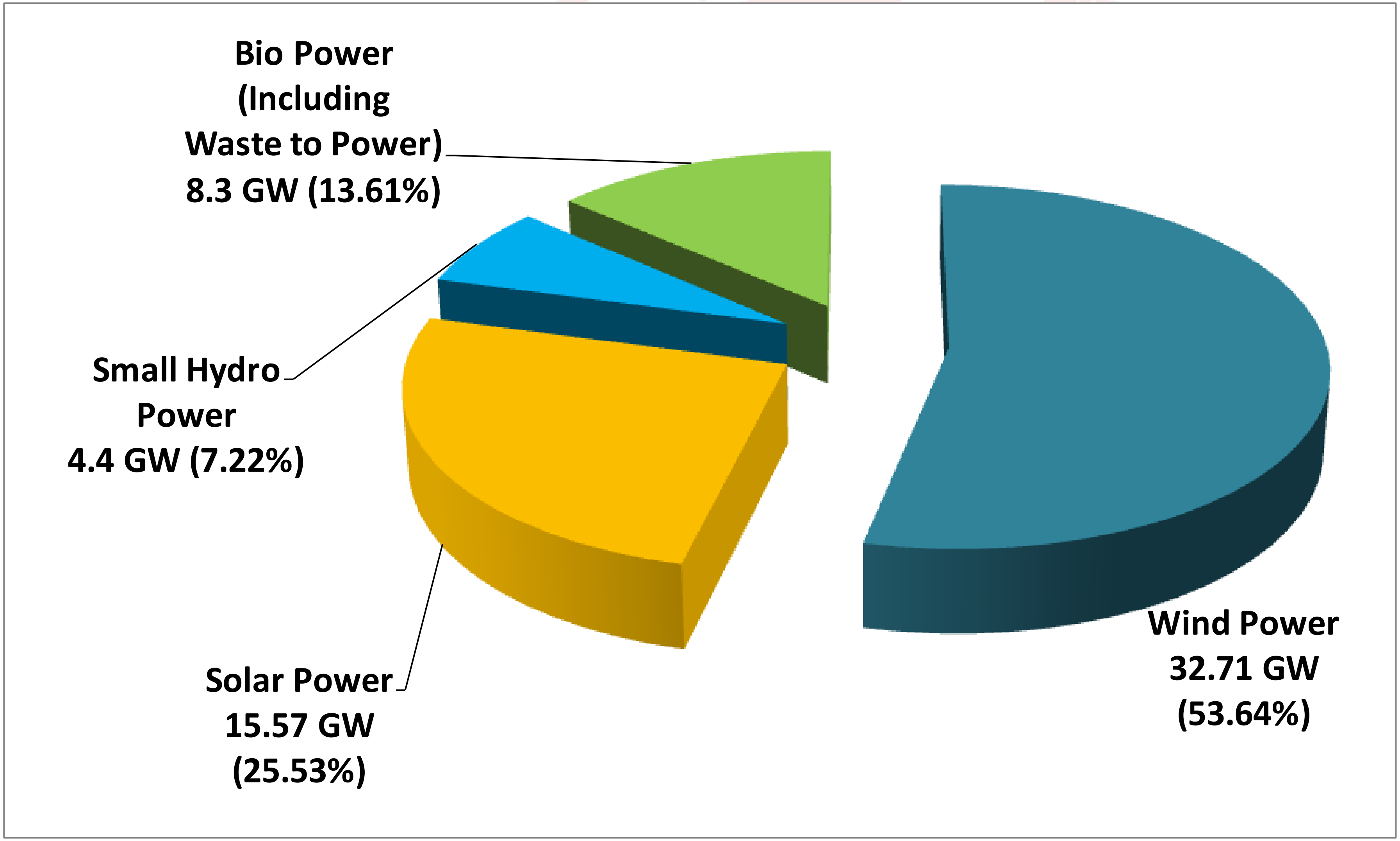
Share of Renewable Energy (Indian context)

Installed capacity : 332 GW



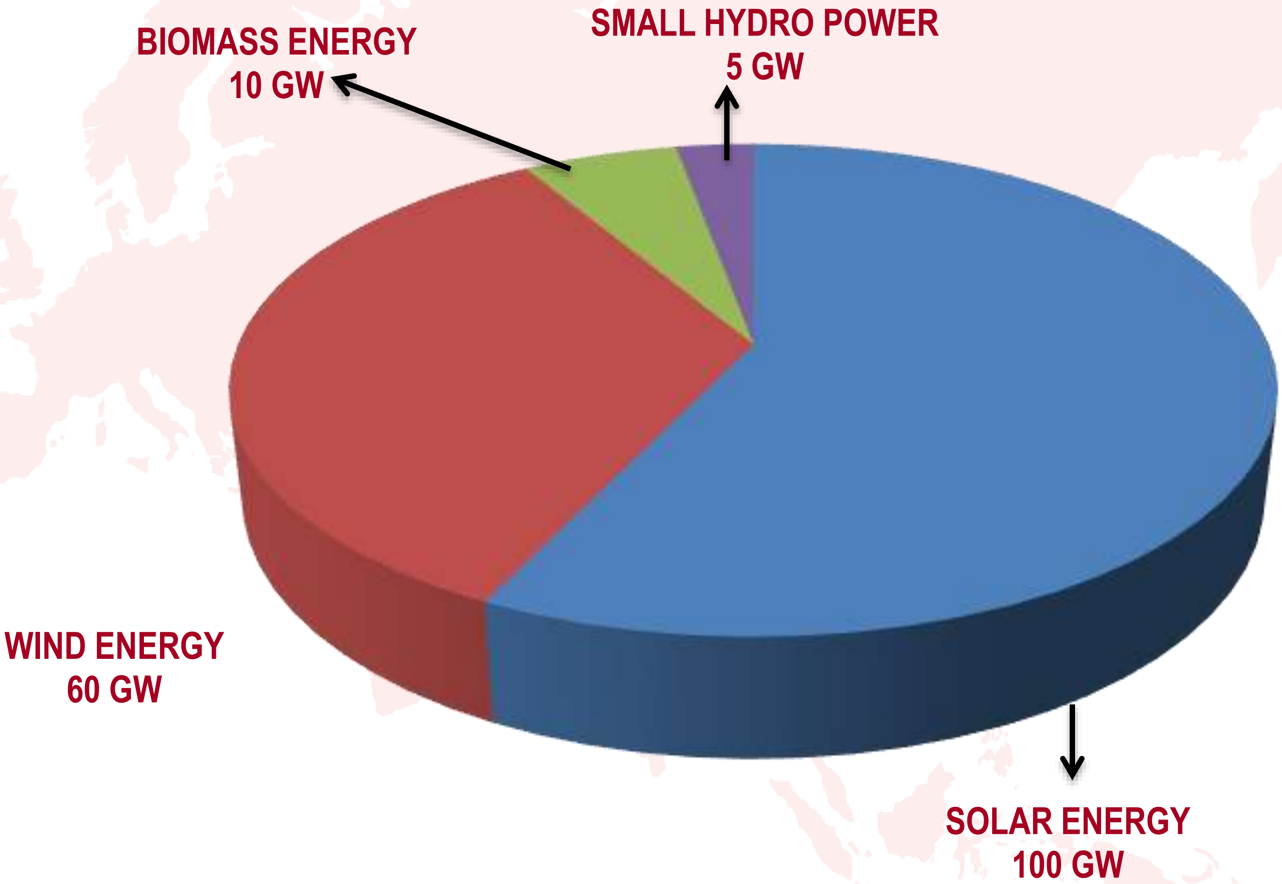
Inter share of Renewables

Installed capacity : 61 GW



Mission 175 GW by 2022

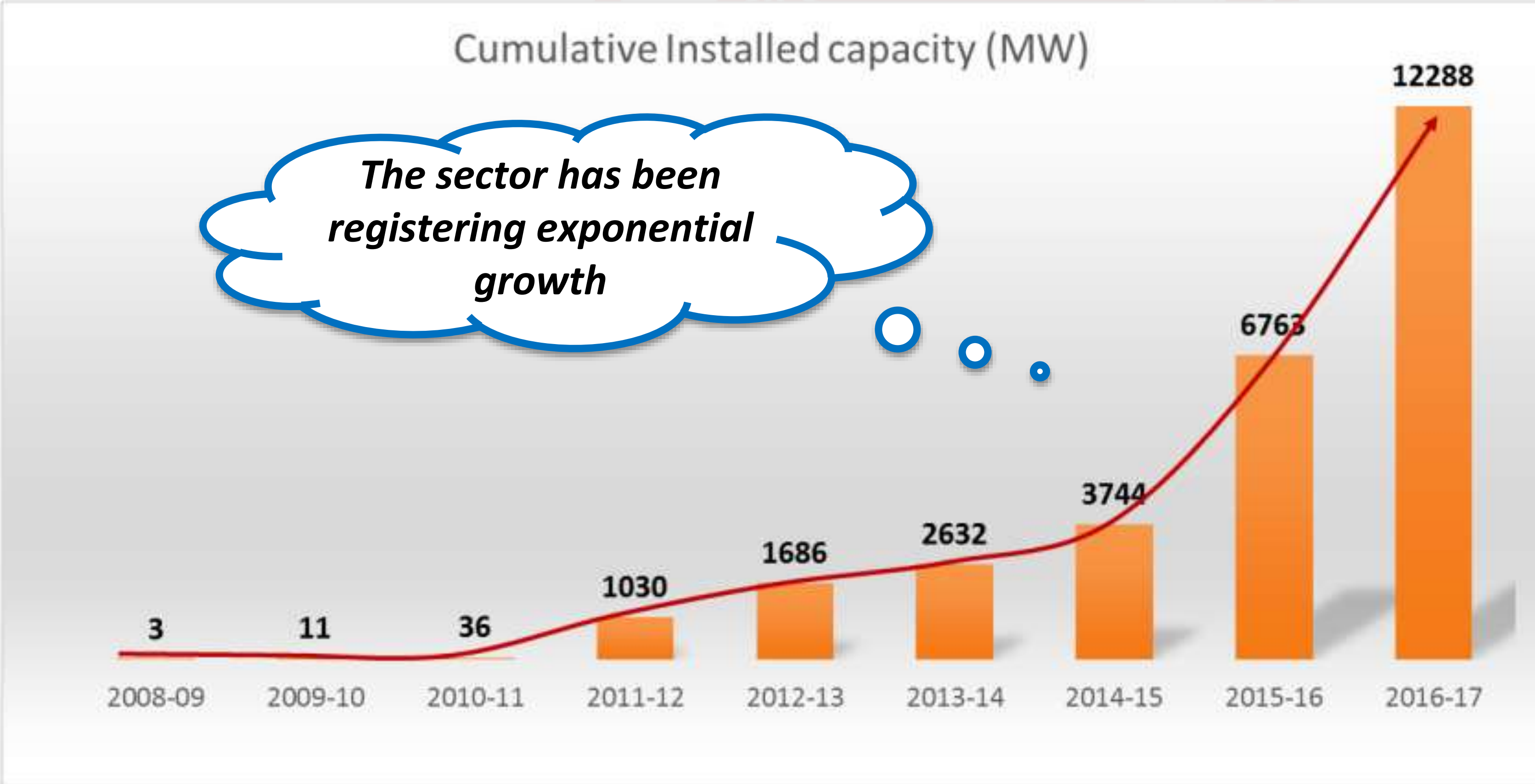
- India made a commitment in Paris Climate Agreement
  - to reduce emission intensity of the economy and
  - for having at least 40 % electric power installed capacity from clean energy sources by the year 2030



National Solar Mission (NSM)

- National Solar Mission (NSM) was launched on 11th January, 2010.
- Mission targets :
  - (i) 20GW grid connected solar power by 2022;
  - (ii) 2GW off-grid solar applications including 20 million solar lights by 2022;
  - (iii) 20 million sq. m. solar thermal collector area;
  - (iv) to create favourable conditions for developing solar manufacturing capability in the country; and
  - (v) support R&D and capacity building activities to achieve grid parity by 2022.
- In June 2015 the targets were scaled up to 100 GW by 2022
- Broadly consists of 40 GW Grid connected Rooftop and 60 GW large and medium size land based solar power projects.

Growth of Solar Capacity in India



Solar penetration in CESC

	Capacity (MW)	Number of consumers
HT	18	41
LT	1.7	134
CESC Establishment	0.05	5
Total	19.75	180

Loading pattern of a grid connected HT consumer having own PV generation

Power Quality problems in Grid

- Over voltages during feed-in
- Short and long time voltage fluctuations (including Flicker)
- Frequency deviations
- Voltage dips
- Unbalance

Other phenomena originating directly from power electronics often used for grid connection such as:

- Harmonic injection
- Resonance phenomena
- Capacitive inrush currents

Of these power quality problems, the most important ones are over voltages and harmonics injection from power inverters

Ways to mitigate PQ issues

The commonly suggested strategies for voltage control

- **Storage device approach** – Storage of excess power from PV to regulate voltage profile (Use of lead acid or Li-ion batteries)
- **Reactive power control** – Increase the number of PVs in such that individual inverters will absorb or inject reactive power in the network
- **Reactive power compensation** – Use of device STATCOM
- **Active power curtailment approach**

[Unified Power Flow Controller (UPFC) – Controls simultaneously all three line Parameters (Line impedance, voltage & phase angle) and also mitigate harmonics
Combination of STATCOM & SSSC
STATCOM – Static Synchronous Compensator
SSSC – Static Synchronous Series Compensator]

In the renewable perspective smart grid is the combination of the established mitigation measures (Distributed battery energy storage system, reactive power support, active power curtailment etc) and real-time communication to address the negative impact of renewable integration and making these measures to operate independently and automatically.

Thank you