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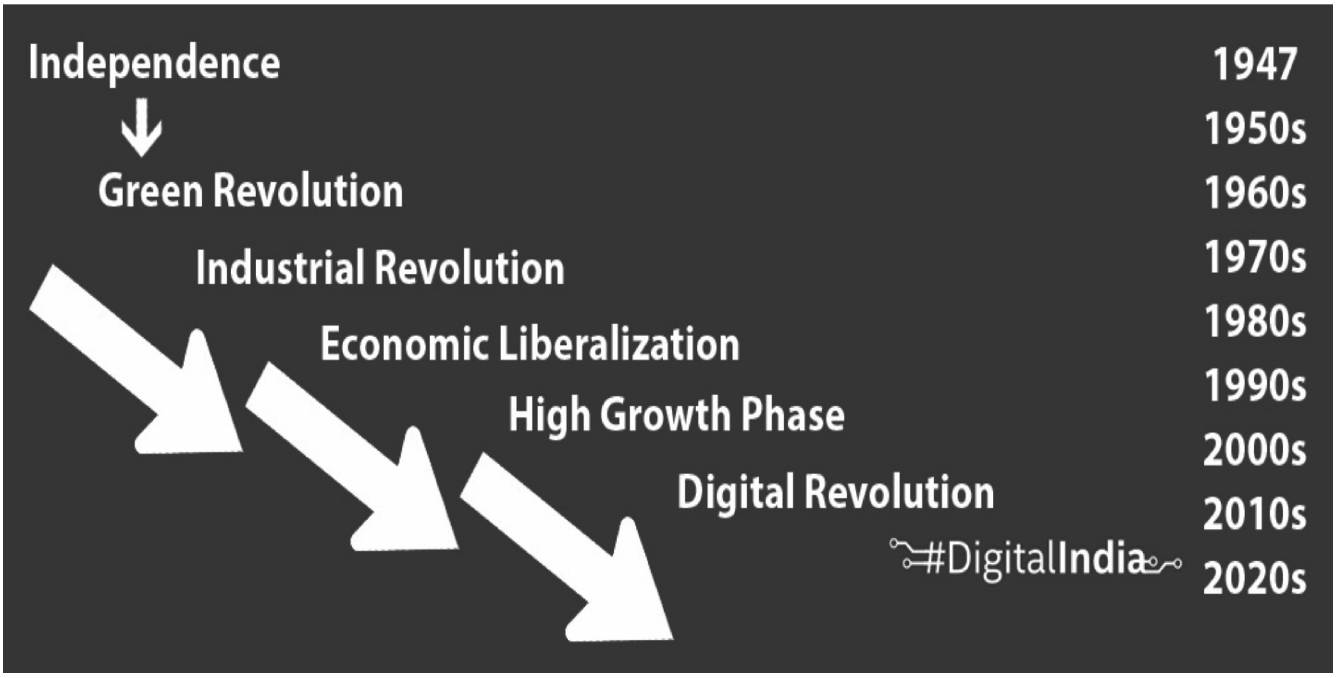
Digital India
Power To Empower



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Er. N Dinker

ACKNOWLEDGEMENT

SPE(I) Vadodara has received donations from the following members :

Er. BC Gajjar	Life Member	Rs. 1,000/-
Er. SM Godkhindi	Life Member	Rs. 1,000/-
Er. NM Pandya	Life Member	Rs. 1,200/-
Er. KH Patel	Life Member	Rs. 500/-

In addition, following Faculties of Seminar for College students at Vasvik Auditorium on 24 Jan 2016, have not accepted their honorarium for lecture in the Seminar as a good will gesture to SPE(I) to help it financially. This is also treated as donation to SPE (I) Vadodara.

Er. GV Akre (Hivoltrans),	Life Fellow
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Late Er. BS Dhora (GSECL)	Life Member
Er. Keval Velani (TPEC)	Well-wisher
Er. RP Sharma (Consultant)	Life Member
Er. RK Tyagi (Apollo Tyres)	Well-wisher

SPE(I) Vadodara Chapter thanks to above donors. SPE(I) further expects similar gesture from members as well as from well-wishers.

Future Programmes

- 1-Day National Seminar on **"Digital Applications in Electrical System"** is organized by SPE(I) Vadodarawith GETCo as knowledge partner on 30 Apr. 2016 at the Auditorium of FGI Business Centre, Gotri-Sevasi Road, Sevasi, Vadodara-391 101. Please Visit SPE(I) Vadodara Website : www.spevadodara.in, for more details.
- It was planned to organize 1-Day Workshop on **"Power System Infrastructure to Bridge Gap between Academicians & Practicing Enginers"** on 06 Apr 2016 at Bhuj. However, Due to unavoidable circumstance the same has been postponed to July/Aug. 2016

From The Chairman's Desk

The role of Academy in shaping the future of the country is being lauded since independence. In the later forties then in fifties the then government started paying attention to this issue. All the education was given either free or at a negligible cost. The technological advancement and rapid industrialization resulted in to demand for engineers and skilled man power. The government brought in Indian Institute of Technology colleges (IIT) and Regional Engineering colleges (REC).

The decade starting from 1990 saw a swing in industrial development and international trade. The demand for engineers started escalating. The beginning of 21st century saw a grave shortage of qualified engineers and technicians. At this juncture, some entrepreneurs saw a big opportunity in establishing engineering colleges in the private sector on capitation fee model. The middle class and rich class of parents who could not secure admission for their low scoring children in 12th standard, in the government owned colleges, turned to such colleges. The supply and demand started getting balanced by the turn of 2010.

The global slowdown had effect on the Indian Economy. The situation today is at such a pass that there are thousands of engineering colleges across the country. It is difficult to get qualified teachers for all these colleges. The result is poor quality of education and low caliber of pass outs. The job opportunities are far less compared to number of pass out every year.

The rank and file of SPE(I) has been watching the development and now has taken an initiative to interact with the engineering colleges for training the final year students for industrial sector. The power sector is the biggest infrastructure which increases the pace of development of other infrastructures.

The volunteers of SPE(I) are working closely with the Academy and try to reach out the students and the teachers for their industrial (practical) knowledge. There has been an inertia from the colleges to this attempt by SPE(I) but it appears that some colleges have made up their mind to work with SPE(I). This is a good sign. As a matter of fact many members of SPE(I) are helping college students for their project work and training needs.

Recently the chapter organized a 1-Day seminar for Electrical Engineering Students at Vasvic Auditoriom, Vadodara. Expert and exponents in the field of power engineering were roped in as faculty. This was followed by a 2-Day interactive seminar at Parul University, Waghodia, Vadodarafor Electrical Engineers. This was followed by three day's practical training/factory visit for the benefit of participating students.

SPE(I) has planned number of such events in next academic year, which is an attempt by industries to reach out to the students. Let us all, in SPE(I), unite and work for bridging the gap between Academy & Industry.

G.V. Akre

Chairmen

Editorial

The word "System" is used to define number of practices being followed in the world. It may be political, social, educational, cultural, financial, governmental, engineering, medical etc. As power engineers we talk about "Electrical Power System". Normally, a system is conceived by an individual, who shares it with his/her close group. The system grows faster when it is accepted unilaterally by all the connected persons. The system is influenced by time, place, temperament of leader and people, financial status, environment, resources etc.

The success or failure of a system depends upon its ultimate utility and its acceptance at large. One must realize that life is not possible without systems of body and nature.

The system of earth and universe is unique

Editorial

and defined in its own way known to us and even unknown to us. For example, the cycle of seasons all over globe is defined. Depending upon where you are positioned on the globe, will give you an idea as to how seasons will change and affect your daily routine. However, cyclone, flood and epidemic come unwarranted though they are now forecast. The earthquake on the date is most unpredictable phenomenon.

The political system in each of the country depends upon internal and external factors. The political system in some countries works on the whims of an individual or an influential group. This leads to instability within the country as well as in the neighboring countries. Today's world is undergoing lot of uncertainty and threat from various radical groups.

Coming to the power system there are some established practices in the state as well as the region. During early days of power system, there was DC distributed generation. The voltage drop prevented a larger system. The invention of AC system brought great relief due to flexibility in stepping up and down the voltage. This AC system afforded long distance transmission with reduction in voltage drop and line losses. Centralized generation became order of the day. Super Thermal Power Stations on the coal mine pit head and long distance transmission resulted in to increase in the voltage exponentially. 11 kV & 33 kV became out dated and now 765 kV AC system has become very common. The 1200 kV AC transmission system is now round the corner.

The system designers were not happy with AC system due to stability issues. The Inductive and Capacitive inductance vary with length and the loading conditions. The power electronics (FACT Devices) also have limitation while supporting the AC system.

The system designers, therefore, thought of returning to old age DC power system. It all started with a cross country DC cable in Scandinavia some more than 35 years back.

The overhead version also started picking up and now we have large number of $\pm$ 500kV HVDC lines in the country. We also have now $\pm$ 800kV line connecting North East to Agra. HVDC line can carry large block of power over a very long distance, without causing system instability during erratic load variations. It also prevents cascade tripping, as it is independent of frequency. The disadvantage of HVDC is that it needs HV AC system at both the ends. Besides it is difficult to have HVDC grid and transformers. The scientists are now working on establishing HVDC grid and HVDC transformers and other controlling switchgears. Once this is done, HVDC will be a preferred option for enblock transfer of power, with an assured system stability against erratic load variation.

The renewable generation is DC and distributed. As of now, the integration with the grid needs conversion from DC to AC. Once DC & HVDC transmission network is established, we will be back in the era when electricity was invented and DC generation of distributed nature was in vogue. These days are not far.

SM Takalkar, Editor

Gentle Request

Members of SPE(I) Vadodara and readers, who desire to have SPE NEWS Letter in soft copy, are requested to indicate their choice through e-mail to SPE(I) Vadodara office. This will help reducing printing as well as dispatch cost of SPE NEWS Letter.

Members who do not yet get invitation of monthly lecture programme through SMS & e-mail, are requested to confirm their correct mobile no. & e-mail address to SPE(I) Office.

Members in NEWS

The companies named as **Takalkar Power Engineers & Consultants, (P) Ltd. & Power Cosultants and Agencies** have jointly completed 10 years of incorporation. The spirit behidn these companies is Er. SM Takalkar, who is Vice-Chairman and Founder Secretary of SPE(I) Vadodara Chapter. Congratulations to Er. SM Takalkar and the other members of SPE (I) Vadodara, who are his Associates.

Chapter's Activity

- On 24Jan 2016, the Chapter organized a 1-Day Workshop on "Electrical Engineering aspects in Power System" at Vasvik Auditorium. The following faculty members delivered the lectures on various topics..

Sr. No.	Faculty (Name & Status	Subject
1	P Ramchandran, Consultnt, L&T	General Power Scenario of India.
2	GV Akre, Director, Hivoltrans	Instrument Transformers.
3	GR Patel, Consultant	Switchgear Equipment Switchgear.
4	PA Shah, Practicing Engineer	Hydro-Electric Power.
5	S M Takalkar, MD, TPECPL	Construction of Transmission Lines.
6	VJ Thakar, Consultant	Protection Relay for Plant & Switchgear.
7	KG Gaikwad, DGM, TPECPL	Substation Design & Engineering.
8	Late BS Dhora, EE, GSECL	Generator Excitation, Auxiliaries & Ancillaries, Switchgears for Plant and HTMotors.
9	PK Tyagi, GM, Apollo Tyres	Industrial Electrification.
10	Keval N. Velani, Engineer, TPECPL	Gas Insulated Substation : Design & Engineering
11	RP Sharma, Consultnt	Career Planning.

Er. Bhadresh S. Dhora started delivering the lecture on "Excitation System for Generators" but collapsed in the initial stage of his presentation and met with untimely death. Er. SJ Shukla was to deliver a lecture on "Automation in Distribution System" but he could not do it due to emergency of rushing Er. Dhora to the hospital and then organizing post death formalities, as Er. Dhora was very close to him. (See photograph of Er. Dhora clicked a moment before his collapse).

The event was organized for the benefit of final year students of Electrical Engineering from various colleges around Vadodara. It is believed that large number students find jobs in Power System Utilities and allied industries. We have received a good feed back from the participants. The chapter is keen to organized similar events in near future. Er. S. K. Negi MD GETCO & All India President of SPE (I) came to the venue while Er. Dhora was being rushed to hospital. Er. Negi addressed the students and remained there till end of the workshop.

- On 06 Feb 2016, the Chapter organized a lecture on the topic of **"Internet of Things"** at Vasvik Auditorium. The lecture was delivered by Dr. Vijay K Shah, Sr. Principal Engineer,BU PPMV, ABB-Vadodara. During his talk he mentioned that electronic technologies have become inseparable to human life. With rapid advancement & convergence of Information, Communication & Entertainment domains, Internet has become a vital link for connectivity.Extending the current Internet and providing connection, communication, and inter-networking between different devices and physical objects, or "Things," is a growing trend that is often referred to as the Internet of Things (IoT). Smart Grid, Smart cities, Smart Village etc…have been some of the popular terms which have been offshoot of the broad umbrella of end usage application domain of the IoT.

During Presentation, above aspect of IoT were addressed, starting with fundamentals and encompassing: What is Internet of the Things, What is its History and Future, What have been different Enabling Technologies, How it affects individual life, What have been its different Applications, What are Advantages & Challenges of using it, What future opportunities it brings for the engineering community covering both Electrical and Non-electrical disciplines, as well as for common man. Effective weaving of technical illustrations from Power distribution, energy management & Utilities domain as well as day to day life, during the presentation, helped in arousing queries from lively audience on the emerging IOT technologies.

Chapter's Activity

❖ On 15, 16, 17, 18 & 19 Feb 2016 the Chapter organized a **5-Day Event** in Parul College of Engineering for their final year students of Electrical branch.

The first two days were allocated for lecture sessions and balance three days were allocated to study visit/tutorials.

The details of lectures is as under.

Sr. No.	Date	Name of Faculty	Subject
1	15^{th} Feb.	VJ Thakar	Protection Relay for Plant & Switchgear
2	15^{th} Feb.	NM Pandya	Operation & Maintenance of Substation
3	15^{th} Feb.	KG Gaikwad	Substation Design & Engineering
4	15^{th} Feb.	JK Thakkar	Construction of Transmission Line
5	15^{th} Feb.	KN Velani	GIS Substation
6	15^{th} Feb.	AK Malek	Electrical Safety
7	16^{th} Feb.	RP Sharma	Career Planning
8	16^{th} Feb.	PA Shah	Energy Management & Energy Audit
9	16^{th} Feb.	SM Godkhindi	Distribution Automation
10	16^{th} Feb.	PA Shah	Hydro - Electric Power

The details of study visits/tutorials is as under.

Sr. No.	Date	Name of the Industry	Details of visit
1	17^{th} Feb.	220kV Substation Waghodia	Outdoor equipment such as Power Transformers, CTs, PTs, Circuit Breakers, LAs, Isolators, Wave Traps, CCs, CVTs, 11kV Capacitor Bank. Bus-bar arrangement Control room equipment such as Control Panels, Relay Panels, 220V Battery & Battery Charger, 11kV Capacitor Bank Power Panel
2	18^{th} Feb.	Danke Power & Distribution Transformers, Waghodia	Step by step processes of transformer manufacturing such as Core assembly, Laying of HT & LT windings, Tanking of core with windings, Drying out and Testing
3	18^{th} Feb.	Maktel Control Systems Waghodia, GIDC	66kV Transformer C&R Panel, 33kV C&R panel, HT Mobile substation with RMU, Operation of various voltage level indoor as well as outdoor breakers. O&T of 66kV Isolators
4	19^{th} Feb.	ABB , Maneja-Vadodara	Functions of all electrical equipment through audio-visual slides. Understanding of internal construction of outdoor equipment through sectional views kept in the outdoor yard.
5	19^{th} Feb.	HT Cable Division, MGVCL Navlakhi, Vadodara	Testing of U/G HT cables for locating the Fault GIS mapping of distribution network of Vadodara City
6	19^{th} Feb.	Concluding Session	Individual interview of students was taken for their Feed Back about the event

In all, 60 students took the benefit of the event, which was a grand success.

Er. DC Mehta,Executive Committee Member, Er. AH Dhebar, Member, Er. ND Makwana, Secretary and Er.JK Thakkar, Advisory Committee Member made arrangements for the event and closely monitored it.

Er. Girish V Jadhav, Professor&HOD(Electrical Engineering), Parul Technical Institute, initiated the event.

- On 28-03-2016, the chapter organized on evening lecture by Er. Vikas Chavda, at Vasvik Auditorium Vadodara. The topic was "Are we prepared?" Er. Vikas Chavda is an innovation expert and specialist in sales and marketing. He has more than 25 years' experience as a coach, trainer, mentor, educator, business consultant and entrepreneur.

  In his lecture, Er. Chavda mentioned that India has been considered as a fastest growing economy in the world. This is good news for those who would like to change with the time and a bad news who simply do not want to come out of the shale. He stated further that thousands of MSME closed down over last few years, because of fast changing technologies. The world's GDP which is around 50% may touch 75% by 2020, which is alarming, he said.

  Finance and global terrorism are the issues which were deliberated by him. Brutal disruption due to the onslaught of technological changes, is bound to affect millions.

  Innovation is the best way to survive in a global scenario. We must try to look at the scenario of a decade ahead. The role of HR is going to be a vital factor in the growth of economy.

  There were many questions on the topic from the audience. Er. ND Makwana, Secretary SPE(I)-Vadodara and Er. N M Bhatt of IE(I)-Vadodara briefed about the way of presentation of Er. Vikas Chavda. Er. SM Takalkar, Vice- Chairman SPE(I)-Vadodara read out the bio data of Er. Vikas Chavda.

OBITUARY

Late Er. BS Dhora, Executive Engineer, Gujarat State Electricity Corporation Ltd. (GSECL) left for his heavenly abode on 24 Jan 2016. He suffered massive Heart attack while he was delivering a lecture on 'Excitation System for Generators' and collapsed in the Vasvik Auditorium, the Institution of Engineers(I), Vadodara.

He was one of the faculty members in the 1-Day Workshop on Electrical Engineering related to the Power Generation, Transmission, Distribution & Utilization, organized by the Society of Power Engineers (I) Vadodara for the benefit of final year students of different Engineering Colleges around Vadodara.

Er. Dhora had almost mesmerized the participants by his presentation and no one had even slight indication of the tragedy which was to fall midway.

Er. Dhora was a great social worker. He was a Managing Trustee of Asha Cancer Care Foundation. He provided training to the staff members and valuable services to SPE(I) Vadodara as well. His untimely death has sent shock waves in the rank and file of erstwhile GEB units. In his death, SPE(I) Vadodara has lost a good trainer and a well-wisher.

At the end of the workshop the students and the faculty members (Including Er. S K Negi) paid rich tributes to Er. B. S. Dhora and observed 2 minutes silence in respect of the departed roul.

May God give peace to the departed soul and give strength to his family members to bear the impact.

Random Thoughts - LIFE - Living with Faith

Let us start our journey through a story............

Once a man got lost in the desert. Water in his travel container had run out two days earlier. He knew that if he did not get some water soon, he would surely perish.

And then he saw a shack ahead of him. He thought it might be a mirage or hallucination, but having no other option, he realised it was quite real, so he dragged his weary body to the door.

The shack seemed to have been abandoned for quite some time. The man gained entrance, hoping against hope that he might find some water inside. His heart skipped a beat when he saw what is inside the shack: A water pump. It had a pipe running down through the floor, perhaps taping a source of water deep underground.

He began working the pump, but no water came out. He kept at it and still nothing happened. Finally he gave up from exhaustion and frustration. He threw up his hands in despair. It looked as if he was going to die after all.

Then the man noticed a bottle in one corner of the shack. It was filled with water and corked up to prevent evaporation. He uncorked the bottle and was about to gulp down the sweet life giving water when he noticed a pices of paper attached to it. Handwriting on the paper read: "Use this water to start the pump. Don't forget to fill the bottle when you are done".

He had a dilemma. He could follow the instruction and pour the water into the pump or he could ignore it and just drink the water.

What to do? If he let the water go into the pump, what assurance did he have that it would work? What if the pump malfunctioned? What if the underground reservoir had long dried up? But then...... may be the instruction was correct should he risk it? If it turned out to be false, he would be throwing away his last opportunity to survive.

Hands trembling, he poured the water into the pump. Then he closed his eyes, said a prayer and started working the pump.

He heard a gurgling sound and then water came gushing out. He was going to live!

After drinking his fill and feeling much better, he looked around the shack. He found a penal and a map of the region. The map showed that he was still far away from civilization, but at least now he knew where he was and which direction to go.

He filled his container for the journey ahead. He also filled the bottle and put the cork back in. Before leaving the shack, he added his own writing below the instruction "Believe me, it works".

This story is all about life. It teaches that faith plays an important role in giving. The man did not know if his action would be rewarded or not. Without knowing what to expect, he made a leap of faith.

Anything done for the general welfare of the world, yields return in abundance – but do your act without expecting the return.

- N. DINKER

Photograph of late Er. B. S. Dhora a moment before he collapsed due to Heart failure in Vasvik Auditorium, Institution of Engineers (I), Vadodara.

(For Report see Chapter Activities & Obituary)

IMPACT OF SHUNT REACTIVE POWER COMPENSATION SOLUTION ON POWER QUALITY

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Abstract— this paper starts with brief coverage on Power Quality (PQ), PQ parameters and their impact on power system. It then focus on the reactive power demand and its impacts. It further then discusses conventional and modern reactive power compensation (RPC) solution strategies to overcome losses in transmission line due to reactive power and also improve the PQ parameters. Keeping PQ Performance as objective, it then focus on parametric and performance analysis with MATLAB simulation of shunt connected RPC solutions. Based on the simulation results then different solutions are rated for their relative PQ performance.

Keywords— Power Quality, Reactive Power Compensation, STATCOM, Power Device

I. INTRODUCTION

Power Quality is the growing issue of concern. Within power quality framework, one of the important aspects is reactive power control. Consumer load requires reactive power that varies incessantly and increases transmission losses while affecting voltage in the transmission network. To prevent unacceptably high voltage fluctuations or the power failures that it can result, the reactive power needs to be compensated and kept in balance. Traditionally, this function gets performed by passive elements such as reactors or capacitors, as well as combinations of the two that supply inductive or capacitive reactive power. However, with loads nature becoming very dynamic, How quickly, dynamically and precisely the reactive power compensation can be accomplished, influences its efficiency and have various transmission characteristics to get controlled.

As a part of this major battle and also as a part of the Power Quality drive, modern Reactive Power Compensation technology have also undergone tremendous amount of change starting from the switched capacitors (electromechanical and thyristorised) to active convertor based compensation.

For this reason, slow responded conventional power quality solver, with the help of new generation control techniques, power electronic components and ease of availability of digital controller/DSP, are getting replaced by fast responded power quality solver. Further, due to variety of options becoming available from different semiconductor manufacturers for Thyristor, GTO, IGBT and IGCT, digital controller/DSP with on-chip features, facilitating very high level of on chip integrations, it makes them more preferable for converter-based FACTs Devices and facilitates the new generation of FACTs devices development [1].

Following paragraph gives brief description of section wise details covered in subsequent sections of this paper.

1) Section 2 gives PQ definition and its effect on power system.
2) Section 3 details the reactive power in transmission line and its influences to load terminal voltage in power system.
3) Section 4 list outs the solution for compensation of reactive power.
4) Section 5 provides parametric comparison and performance analysis for conventional and modern reactive power solutions
5) Section 6 then provides relative ratings for the performance of different solutions with respect to power quality related aspects.

II. POWER QUALITY

Power Quality (PQ) is the study of the sources, effects and control of disturbances in electric power system. Due to the disturbances in supply, RMS value of voltage or its wave shape and sometimes even the frequency gets affected. The disturbances, which cause distortion in power supply, originates from variety of sources deploying especially electronic objects (incorporating rectifiers for dc supplies, semiconductor switches etc.), atmospheric disturbances (moisture, temperature etc.), dynamic loads, saturated electromagnets or faults arising within the plant etc.

In other way, power quality can also be looked as a compatibility problem. Compatibility problems always have at least two solutions: in this case either clean up the power, or make the equipment tougher [2].

PQ problems can be broadly classified into two categories,

A. Amplitude Disturbances:

Amplitude disturbances can be further classified into two categories, periodic and transient.

B. Wave shape Disturbances:

Wave shape disturbance can also be classified into two categories, current and voltage.

The various PQ problems as a possible cause and their effects as a symptom are listed in below Table 1.

TABLE - I

POSSIBLE CAUSES ASSOCIATED WITH SYMPTOMS

Sr.No.	Symptom (Effect)	Possible Cause
1	Overload neutral	Harmonics
2	Trip-out of motor drive or PLC	Sag, under voltage, or oscillatory transient
3	Destruction of electronic equipment	Impulsive transient
4	Clock resetting	Sag or under voltage
5	Racing clock	Harmonics
6	Light flicker	Voltage fluctuations
7	Capacitor fail	Harmonics
8	Overheating motor	Under voltage, unbalance & harmonics
9	Light globes fail excessively	Over voltage or swell
10	AC contractor trip-out	Sag or under voltage
11	Variation in motor speed	Sag/swell or under/over voltage
12	Insulation failure	Over Voltage

From the above table it is very easy to observe that Power System is mostly affected by PQ parameters like Sag, Swell, Over Voltage, Under Voltage and Harmonics. Apart from the Harmonics, in Power System sag, swell, under voltage and over voltage are mostly arrested by Reactive power and therefore the issue of Reactive power is included in the ambit of PQ consideration.

III. REACTIVE POWER -FUNDAMENTALS

When Power is supplied to a load through transmission line keeping the sending end voltage constant, the receiving end voltage goes under variations, depending upon the magnitude and the power factor of the load. Higher the load, with smaller power factor, the greater is the voltage variation. The voltage variation at a node is an indication of the unbalance between the reactive power generated and consumed by that node. If the reactive power generated is greater than consumed. The voltage goes up and vice versa.

To understand clearly let us consider the following example in which node one is a generator node with reference voltage V1 and node two is the load node with voltage V2 (Fig. 1). The two bus bars are interconnected through a short line represented by inductor X. whereas P & Q are active and reactive component of load.

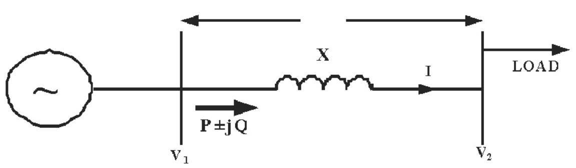


Fig.1 Load connected to the source through a line

$V_1 = V_2 + V$ where $V = j\, I\, X$ ……………….. (1)

$V_1\ I = (P\ j\,Q)$ ……………….. (2)

Where, -ve for Inductive Load
+ve for Capacitive Load

$I = (P\ j\,Q) / V_1$ …………………………………. (3)

$I = (P/V_1)\ j\,(Q/V_1)$ …………………………. (4)

$I = I\cos\ j\,I\sin$ ………………………………….. (5)

From equation (1) & equation (4)

$V_2 = [V_1\ \{(Q/V_1)\ X\}] - j\,[(P/V_1)\ X]$ …..... (6)

Where, -ve for Inductive Load
+ve for Capacitive Load

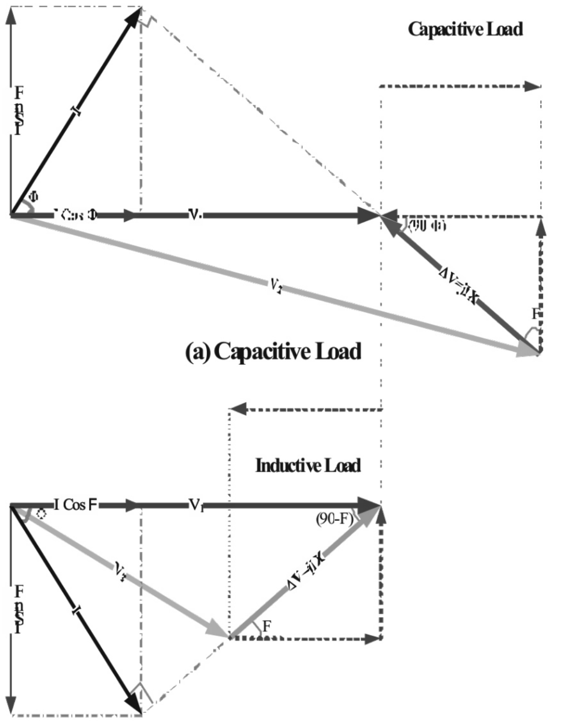


Fig.2 Influence of active and reactive power flow on system voltage

From the above Fig.2, it is clear that the load voltage V2 is not affected much due to the active component of the load (P) as it is normal to vector V1 whereas the reactive component of load (Q) is directly added to or subtract from the voltage V1 respectively. Therefore the voltage regulation in V2 is directly proportional to the reactive power Q.

The relation is given by,

$V_2 = [V1\ \{(Q/V_1)\ X\}]$ …………………… (7)

Where, -ve for Inductive Load
+ve for Capacitive Load

Further, in overall context Reactive power flow has the following effects:

1) Increase transmission system losses which leads requirement of more power plant installation capacity and hence increasing operating cost.

2) Major influence on system voltage deviation which triggers degradation of load performance at under voltage and risk of insulation breakdown at over voltage.
3) Power carrying capacity of transmission line bounded by line thermal limit so increment in losses reduces power carrying capacity of line as a result dynamic stability limit diminished.

IV. SOLUTION STRATEGIES

Solution strategies for preventing individual or small groups of loads from drawing current, of an undesirable nature can be of two types.

a) Local Solutions:

Electrical equipment, which is yet to be commissioned, can be redesigned to take care of possible extremities in the PCC voltage fluctuations. This improves their so-called "ride-through" capability.

This reduces the harmonic component of the current, drawn from the utility, to acceptable limits.

b) Global Solutions:

In the second approach, where the redesigning is not feasible, one has to provide additional suitable compensating devices at selected locations in the Transmission & Distribution system, so that the overall PQ situation is improved.

Using FACTs as Reactive Power Compensation solution, the present transmission system operation can be improved with minimal infrastructure investment, environmental impact, and also minimal implementation time compared to the construction of new transmission lines.

FACTs Devices can be classified as shunt, series and series-shunt connected Compensators [3].

Addressing, Series and Series-Shunt Compensators, this paper further describes Conventional and Modern Shunt Compensators.

A. *Conventional Reactive Power shunt compensation Solutions*

Conventional RPC solution includes FC (Fixed capacitor), APFC (Automatic Power Factor Correction) and thyristor based RPC solution i.e. TSC (Thyristor Switch Capacitor), TCR (Thyristor Control Reactor) and SVC (Static VAr Compensator).

1. *FC and APFC compensation Solution*

Fig. 3 represents scheme for FC will provide fixed compensation with response time equal to capacitor energise time at system voltage level. Whereas APFC will provide the stepped compensation. However, the response time is equal to switch (Non-electronic type) turn on time, plus capacitor energise time.

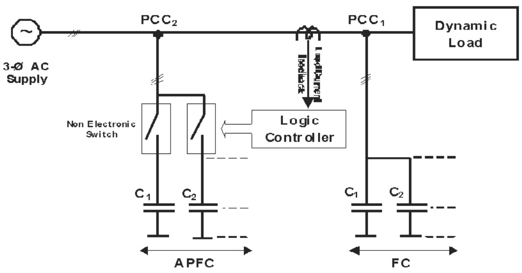


Fig.3 Fixed Capacitor and APFC Some key aspects for this solution are

- Fixed capacitor provides only single step compensation.
- APFC provides N-step compensation with N number of Switch-Capacitor pair. This solution will be costly and complex to achieve smooth compensation.
- Stepwise improvement in the % load regulation and source power factor during inductive load.
- No harmonic injection into supply.
- Performance of FC or APFC depends on fault level.

Although, FC has a limitation to compensate the demand of reactive power which is dynamic in nature but it is most suitable and cheap solution to the non-dynamic inductive load.

2. *TSC (Thyristor Switch Capacitor) compensation*

Fig. 4 represents a shunt connected thyristor switched capacitor whose effective reactance is varied in a stepwise manner by full or zero conduction of the thyristor. TSC can provide stepped compensation with response time equal to thyristor turn on time plus capacitor energise time.

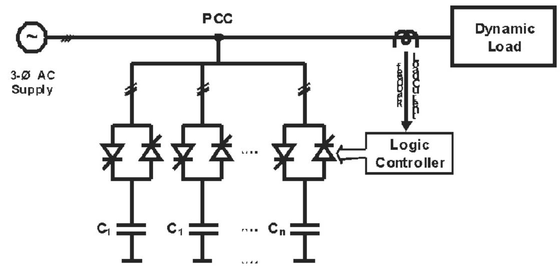


Fig.4 TSC

Some key aspects for this solution are

- It provides step compensation same like APFC but with comparatively faster response time.
- It also provides stepwise improvement in the % load regulation and source power factor during inductive load.
- No or minimal harmonic injection into supply.
- Performance of TSC depends on fault level.

3. *TCR (Thyristor Control Reactor) Compensation*

Fig. 5 represents scheme for a shunt connected thyristor controlled inductor whose effective reactance is varied in a continuous manner from fully to partially conduction of thyristor by controlling firing angle.

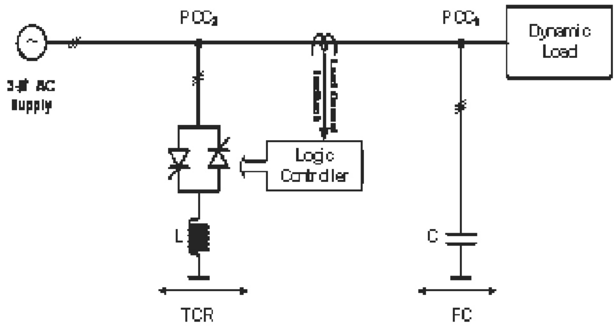


Fig.5 TCR with FC

Some key aspects for this solution are

- It provides smooth variable inductive reactive power compensation by controlling thyristor firing angle.
- It gives faster response than FC and TSC.
- It also improves the % load regulation and source power factor during capacitive load.
- Intensity of Harmonic injection into system depends on firing angle.
- Performance of TCR with FC also depends on fault level.

4. *SVC (Static VAr Compensation)*

Fig. 6 represents scheme for a shunt connected static VAr generator or absorber whose output is adjusted to exchange capacitive or inductive current to maintain or control specific parameters of the electrical power system [4].

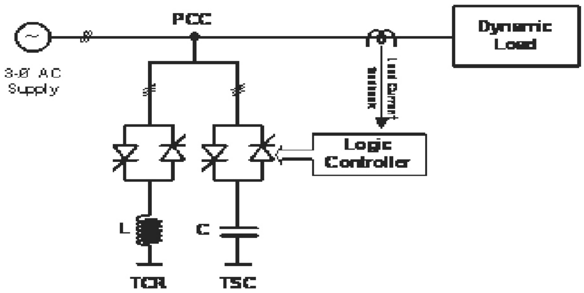


Fig.6 TSC & TCR

Some key aspects for this solution are

- It provides smooth variable reactive power compensation.
- It gives faster response than FC and TSC.
- It also improves the % load regulation and source power factor for both inductive and capacitive load.
- Intensity of Harmonic injection into system depends on firing angle.
- Performance of SVC depends on fault level.

B. *Modern convertor based Reactive Power shunt compensation Solutions*

Fig. 7 represents scheme for Static Synchronous Compensator operated as a shunt-connected static VAr compensator whose capacitive or inductive output current can be controlled independent of the AC system voltage. STATCOM, owing to the technology, has higher investment cost. However, it has a shorter payback cycle; hence it is a preferred choice in performance sensitive application where power quality is not be compromise with respect to cost.

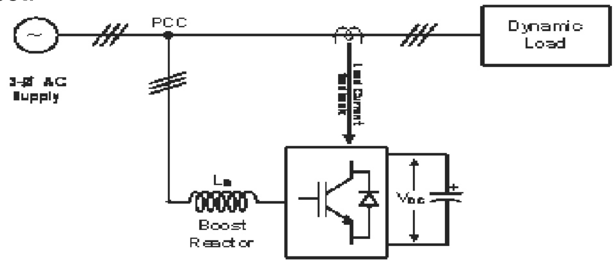


Fig.7 STATCOM

Some key aspects for this solution are

- *Converter based STATCOM gives smooth operation which further improves voltage level of converter from two-level to multi-level and hence improves THD on* supply side.
- It provides very fast response in comparison of conventional RPC solution.
- For the same kVAr rating Convertor based RPC solution is costly compare to conventional RPC solution.
- It also improves the % load regulation and source power factor.
- Its performance dose not depends upon fault level.

STATCOM giving step less compensation with response in few tens of milliseconds without generating the lower order harmonics (current drawn is nearly sinusoidal). It also has a benefit of operating in capacitive as well as in inductive mode.

C. *Window Operated Modern convertor based Reactive Power shunt compensation Solutions*

In most of the application needing Dynamic Reactive Power Compensation (Dynamic RPC) for the lagging power factor nonlinear loads, STATCOM which gives +/-Q compensation can be a choice. However, the installation economics is still dictated by the 50% STATCOM capacity. Fig. 8 represents scheme to overcome this problem, it becomes worth using combination of TSC and the STATCOM together [5] [6].

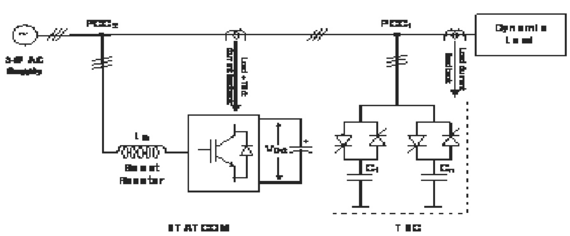


Fig.8 TSC and STATCOM

Some key aspects for this solution are

- Window operated modern converter based RPC gives more smooth operation with very fast response.
- Compensation shared by TSC & STATCOM and hence KVAr capacity of STATCOM reduces which gives cost effective solution.
- It also improves the % load regulation and source power factor.
- Its performance partially depends on fault level i.e. TCS compensation.

V. COMPARISON OF CONVENTIONAL AND MODERN RPC SOLUTION.

Power quality parameters and key aspects have been discussed in previous sections. For further parametric and performance evaluation, these solutions in this section are investigated for different cases, based on different FACTs Scheme, Multi-level Topology, Semiconductor Devices, Control Techniques and Advanced Controllers (DSP) Thyristor based and Converter based RPC solution (FACTs Devices) shown in Table 2.

TABLE II

SEVEN CASES OF RPC SOLUTION (FACTS DEVICES).

Scheme	Topology	Devices	Control technique	Controller	Case
FC	-----	-----	-----	-----	Case 1
APFC	-----	Relay	-----	microcontroller	Case 2
TSC	-----	Thyristor	-----	microcontroller	Case 3
TCR	-----	Thyristor	-----	microcontroller	Case 4
TCR + TSC	-----	Thyristor	-----	microcontroller	Case 5
STATCON	Single Converter	MOSFET, IGBT, IGCT,	SPWM	Microcontroller, Microprocessor, DSP.	Case 6
STATCON	Multi-level Converter	MOSFET, IGBT, IGCT,	SPWM	Microcontroller, Microprocessor, DSP.	Case 7

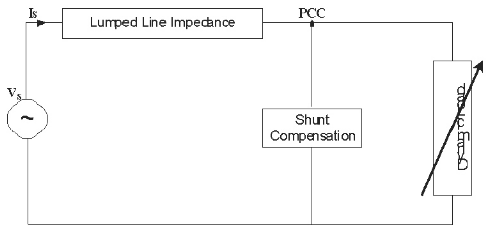
For comparative assessment above seven cases are applied on pre-defined Linear Load which is varying with respect to time (Fig. 9). Linear Load varying with step of 0.1 Sec from 0.0 Sec to 0.9 Sec shown in Table 3 and Table 4.

TABLE III

DYNAMIC LOAD.

Time (in Sec)	Linear Load
0.0 – 0.1	Resistive Load
0.1 – 0.4	Stepwise increased Inductive Load
0.4 – 0.7	Stepwise increased Capacitive Load
0.7 – 0.8	Capacitive Load
0.8 – 0.9	Inductive Load

Fig.9 Block diagram of Shunt Compensation



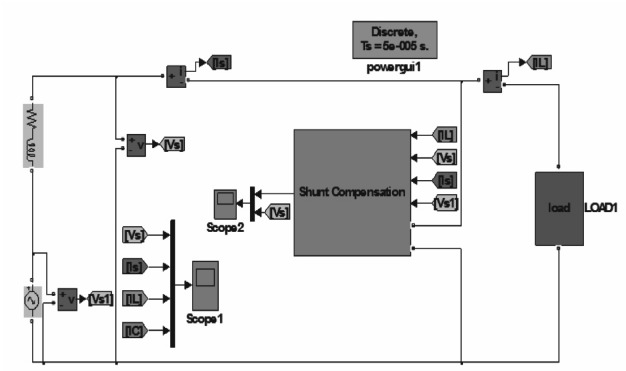


Fig.10 MATLAB Simulation Model of Shunt Compensation.

TABLE IV

Load Defines without Compensation.

Time (in Sec)	Total Load (kVA)	Resistive Load (kW)	Inductive Load (kVAr)	Capacitive Load (kVAr)	Reactive current (Amp)	V_S (Volt)	I_S (Amp)	V_S (THD) %	I_S (THD) %
0.0--0.1	2.5	2.5	---	-----	----	229.6	11.5		
0.1--0.2	9.01	7.5	5	-----	39.43	208.8	63.62		
0.2--0.3	16	12.5	10	-----	71.98	190.7	108.9		
0.3--0.4	23.04	17.5	15	-----	99.09	175	146.5		
0.4--0.5	9.01	7.5	----	5	-46.91	248.4	75.69	0.40	0.19
0.5--0.6	11.8	9.5	----	7	-67.75	255.9	105.2		
0.6--0.7	16	12.5	----	10	-100.07	266.9	152.3		
0.7--0.8	9.01	7.5	----	5	-46.91	248.4	75.69		
0.8--0.9	9.01	7.5	5	-----	63.62	208.9	63.62		

For the above defined load, comparative PQ related performance is then evaluated with and without different compensation solutions.

Supply Source Details considered as follow:

V_S = 230V, frequency = 50Hz

R_S = 0.03, X_S = 0.47, Z_S = 0.471

Results for different RPC Solution Scheme derived from MATLAB simulation model (Fig. 10) are shared below. Finally the section ends with relative ratings for these different cases as shown in Table 6.

Fig.11 represents the impact of short circuit ratio (S.R.) on voltage profile and % load regulation at PCC without any compensation. It also very clear from figure, voltage profile improves with increment in the value of S.R. from 15 to infinite which results in to better % load regulation.

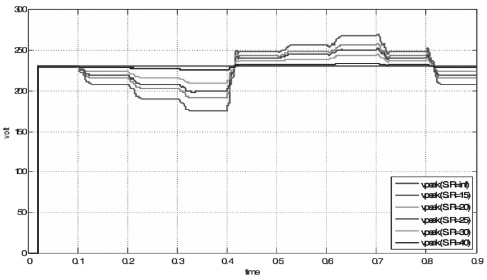


Fig.11 Simulation results of voltage with change in Short circuit Ratio (S.R) at PCC.

Fig.12 shows the comparison of voltage profile and % load regulation at PCC and Fig.13 shows the comparison of source power factor at PCC with consideration of all compensation.

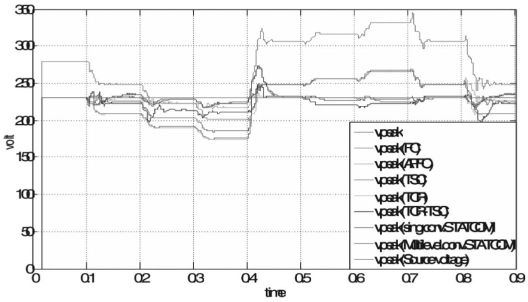


Fig.12 Comparison of voltage at PCC for different compensation solution

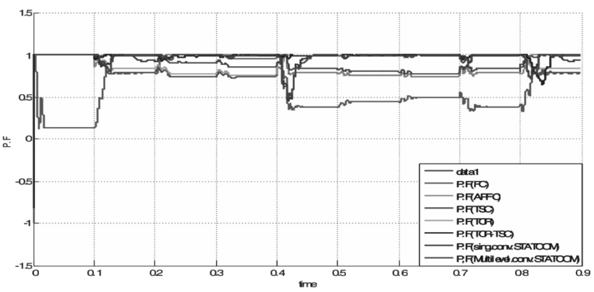


Fig.13 Comparison of source p.f. for different compensation solution.

Fig.14 shows the source currents profile (IS) and their comparison with consideration of all compensation at a single glance.

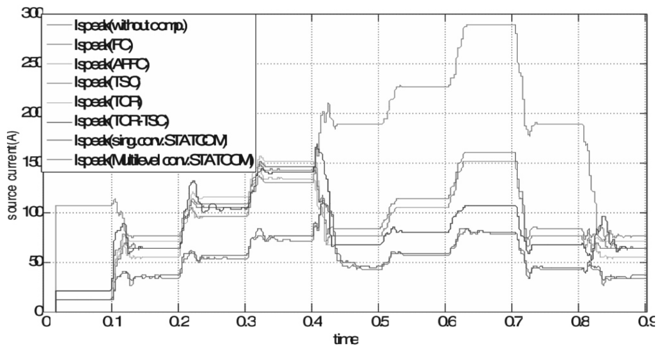


Fig.14 source currents of different compensation solution.

TABLE V

THD OF SOURCE SIDE VOLTAGE AND CURRENT OF ALL THE CASES.

Cases	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Case 1	0.46%	0.67%	0.49%	2.07%	2.88%	1.62%	1.03%
Case 2	0.83%	0.85%	0.82%	3.71%	5.59%	2.25%	1.16%

Performance rating mapping can be considered as below,

1 = Excellent   2 = Very Good
3 = Good   4 = Fair
5 = Poor   6 = Very Poor
7 = Worst,

The performance rating presented above applied for the different cases or the different solution Scheme with respect to Power Quality parameters can be summarized and accredited as below in the Table 6.

TABLE VI

RELATIVE PQ PERFORMANCE RATING OF DIFFERENT SOLUTIONS FOR GIVEN LOAD.

CASES	Harmonics		Voltage (Under/Over)	P.F.	RPC SOLUTION SCHEME
	V_{STHD}	I_{STHD}			
Case 1	**1**	**1**	7	7	Fixed Capacitor Compensation
Case 2	**3**	**3**	4	5	APFC Compensation
Case 3	**2**	**2**	6	6	TSC Compensation
Case 4	6	6	5	4	TCR Compensation
Case 5	7	7	**3**	**1**	TSC + TCR Compensation
Case 6	5	5	**2**	**3**	Single Converter based STATCOM
Case 7	4	4	**1**	**2**	Multilevel Converter based STATCOM

VI. CONCLUSIONS

From the above results, it can be observed that when different cases are evaluated in terms of THD generation, under/over Voltage, power factor etc., Multi-level converter based STATCOM generates less THD as compared to SVC, TCR and Single converter based STATCOM & other solutions. Further, Multi-level converter based STATCOM improves under/over voltage, power factor with compared to other compensators.

Finally, with the various power quality solutions available, the obvious question for a consumer or utility confronting a particular power quality problem– "which equipment provides the optimal solution?", has been effectively addressed in the paper. While, a procedure has been presented in this paper, it is also supported with simulation results.

Further, to these tasks verification of the simulation results on the hardware platform is now considered as future work extension of this paper.

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A NEW VENTURE BY M/s. T&ATSPL, VADODARA.

We are happy to announce that M/s. Trivedi & Associates Technical Service, (P.) Ltd., Vadodara is going to launch a new institute in a short time at **Survey No. 529/2A & 2B, Village Nana Fofadia (Approximate 25 Km from Vadodara) Nr. Bamangam, Taluka, Dabhoi, Dist. Vadodara.** This institute is named as Trivedi Institute of Training & skill development.

The proposed institute will hae a complete infrastructure and facilities for imparting training (Theory & Practical) in various fields as mentioned under :

1) **Training Centre**
   a) Training and skill development under - VTP Scheme, approved by The Director of Employment and Training, Government of Gujarat.
   b) Crane Operator training for various types of cranes on imported Desktop Simulator (USA Made).

2) **Service Centre**
   a) Service Centre for instrument repair, testing and calibration as per ISO & NABL requirements.
   b) Inspection, Repairing, Maintenance and Certification of Lifting Tools & Tackles, Lifting Mechine (i.e. Chain Pulley Block, Hook Chuck, Ratchet Pooler, Monorail, Hydraulic / Mechanical Jack) as per Factory Acts & Rules.
   d) Inspection, testing and certification of
      - Safety Relief Valve as per SMPV Rules 18.
      - Excess Flow Valve as per SMPV Rules 18
      - Pressure Vacuum Relief Valve as per Petroleum Rules 2002.

3) **Authorized Training Centre (ATC) ROOF TOP SOLAR PLANTS**
   a) Authorized Training Centre (ATC) under National Certification programme for roof top solar photovoltaic installer, likely to be granted by GERMI, Gandhinagar.

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