International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V70I3P216

Volume 70 Issue 3, 140-150, March 2022

A Study of ATC Losses, Tools, Techniques and Ongoing Applications in Smart Grid

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Abstract **-** *The requirement & habit of devices and energy are exponentially cumulative day by day. Green energy, clean energy, and energy 24x7 are nothing but the requisition of today's hex. There are a lot of sources/resources of energy that can be converted to electrical/mechanical/light and any other obligatory form. But on the other hand, there are some hurdles/losses that happen during the Generation / Convert / Transmission / Distribution process. We are incompetent to eliminate anything to zero, but it is conceivable to minimize at a confident level. In this paper, we have tried to determine/examine security / technical/commercial losses. Moreover, the study also helps us to propose a solution to condense all types of losses and errors.*

Keywords - *IoT Applications, Tools, Smart Grid, Communication, Power Analysis.*

I. INTRODUCTION

Technology has grown up, and smart/latest devices are introduced daily. Smart grid is a combination of 'Smart,' which means 'smart', and 'Grid,' which means a distribution network for supplying electricity and gas, and a power grid. It is a next-generation power infrastructure system that enables intelligent demand management, new and renewable energy connection, and electric vehicle charging by exchanging real-time information. In other words, it is a service that enables more effective electricity supply management by providing electricity user information to electricity suppliers and producers. If the existing power grid has an analogue/electromechanical, centralized radial structure, manual recovery, fixed-rate, and one-way information flow structure, the smart grid, an intelligent power grid, is a digital/intelligent, distributed system network structure. It has a group structure, automatic recovery, real-time rate, and two-way information exchange. All the devices have performed the task per their installed operating system and supportive features provided by a different technology. But all device tries to operate without an energy source. It won't perform, and this process looks like a vehicle without fuel.

II. SMART GRID TECHNOLOGY TREND: CONVERGENCE TECHNOLOGY OF POWER GRID AND INFORMATION COMMUNICATION

The vision of a smart grid to improve the reliability, efficiency, and safety of the power grid by applying information and communication technology to the existing power grid includes renewable energy such as solar and wind power, electric vehicles (EV), storage devices such as batteries, and demand response. In the smart grid, various technologies such as energy sources, power, communication, software, computing, home appliances, and semiconductors are complexly intertwined, and operators and policies are as complex as technological elements. A next-generation power grid technology that includes the trade of energy resources by distributing power information in both directions and in real-time, and its importance through understanding related technologies, related domestic and foreign policies and market trends, and domestic and foreign technology development I would like to describe the trend.

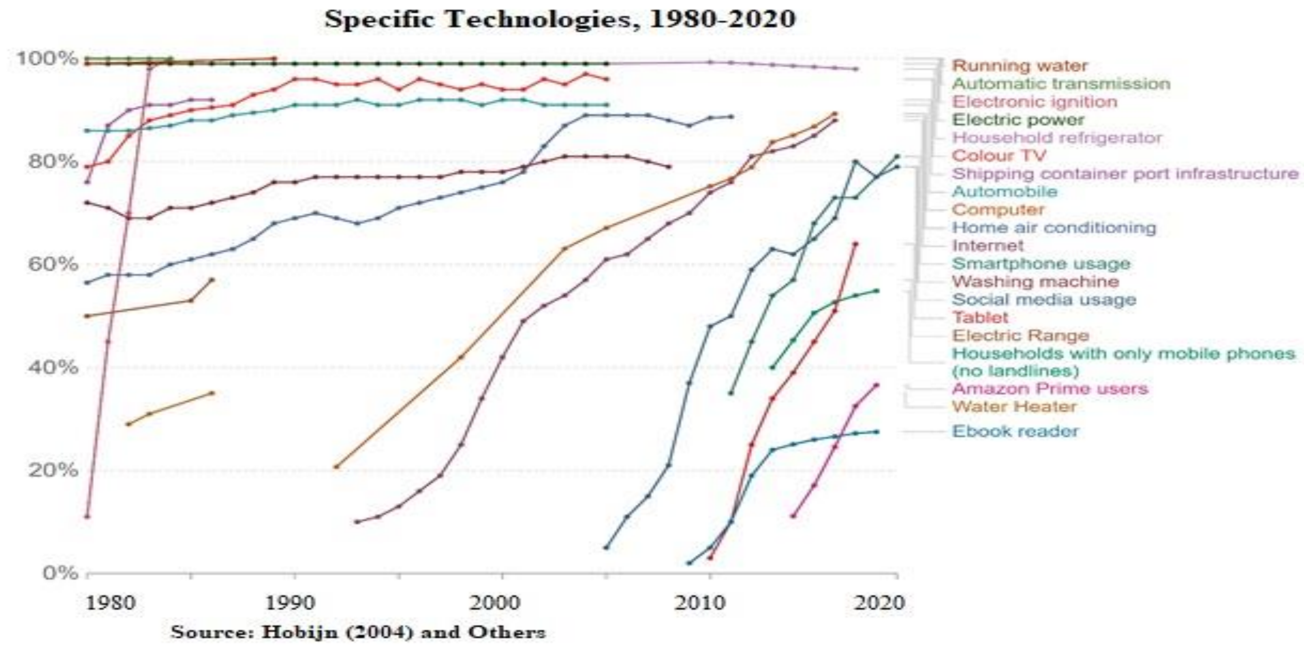

Fig. 1 Technologies: 1980-2020

In recent Years, Due to the high integration of energy resources, the efficiency management system has become more complex. The above Figure indicates that technology integration and energy integration are now up to a confident level. But on the other hand, in terms of fulfilling demand, there are occurred some losses, and there is some difference between supplied power and received power.

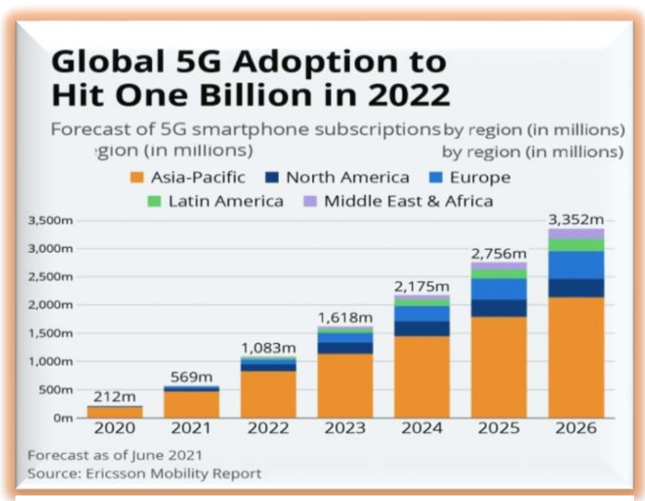

Fig. 2 5G Adoption [40]

To predict the smart grid market, the next-generation growth engine that attracts global attention, it is first necessary to forecast the global population growth and the power equipment market accordingly. The world population is expected to increase by about 2 billion from 6.1 billion in 2000 to 8.1 billion in 2030. Based on this, it is expected that by 2030, the number will increase to more than 2.3 billion people, considering the current power demand exclusion class and new power service customers due to the new population. In addition, electricity demand due to changes in the electric power environment is expected to double from 14,000 TWh in 2004 to 28,000 TWh in 2030.

III. INTERNET OF THINGS (IOT)

IoT means that various electronic devices, vehicles, buildings, sensors, and machinery infrastructure that we encounter in our daily life are connected to the Internet through an information and communication network to collect various data and exchange data between users or devices. When the Internet of Things includes sensors, mechanical devices, and infrastructure, it is not just simple information exchange. Still, it is converged with a cyber-physical system to build and operate a smart grid, a virtual power plant, a smart home, and, more broadly, a smart city. It can be a factor. The smart grid combines information technology, communication technology, and digital control technology in the power sector. It can be said to be the central stage of the Internet of Energy, a field of the Internet of Things, and increased experience or efficiency results in better consumer interaction and control. In addition, IoT will enable denser, more efficient, smarter smart grids, such as providing more information to manufacturers and utilities, reducing diagnostic costs, and allowing town-wide meter readings to be read.

A. Application of IoT

The Internet of Things (IoT) is a technology that connects to the Internet by embedding sensors and communication functions in various objects as one of the core fields of the 4th industrial revolution. The Internet of Things provides various conveniences in our lives. So, in which areas of our lives are the Internet of Things used? According to the 2019 IoT industry survey conducted by the Ministry of Science and ICT, the Internet of Things is being used in various industries. Let's find out in what fields it is used:

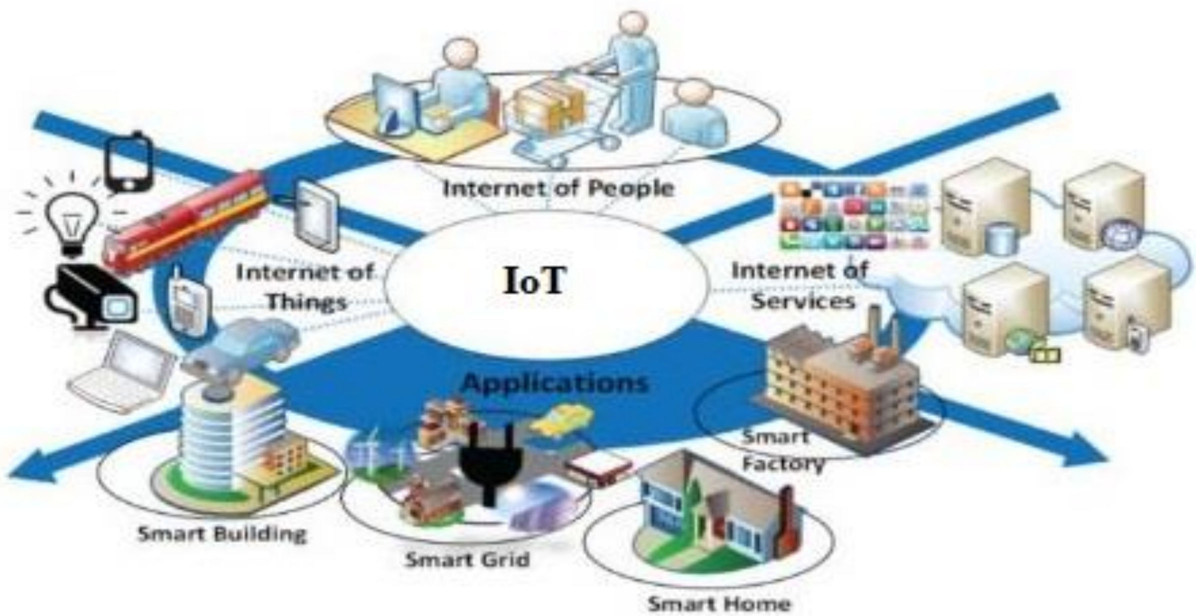

Fig. 3 IoT Applications

Application	Services
Healthcare / Medical / Welfare	**Healthcare:** Exercise Volume Management Service and Sleep Management Service Through Wearable Devices. **Medical Institutions:** Medicines and Medical Device Management Services, Patient Condition Monitoring Services, Remote Examination Services.
Agriculture and Forestry	Agricultural Products Distribution Management Service, Productivity Management Service, and Cultivation Environment Monitoring and Management Service.
Livestock / Fisheries	**Livestock:** Breeding Management Service, Automatic Feed Feeding Service, Livestock History Tracking Service, and Livestock Infectious Disease Management Service. **Fisheries:** Aquaculture Environment Information Collection Service and Fishery Product History Management Service.
Automotive / Transport Infrastructure	**Automobiles:** Vehicle Diagnostic Services, Autonomous Driving Services, and Connected Cars. **Transportation infrastructure:** Intelligent Transportation System (ITS), Public Transportation Operation Information Management Service, Smart Parking Service, Parking Location Provision Service, Nearby Parking lot Information Service, Parking
Tourism / Sports / Leisure / Entertainment	**Tourism:** Tourist Destination Location Information Service, Government or Cultural Event Information Collection and Provision Service, and IoT-based Cultural Heritage Tourism Information Service. **Sports / Leisure / Entertainment:** Athlete Management Service, Sports Equipment Management Service.
Retail / Logistics / Distribution	**Retail:** Intelligent Shopping Customer Management Service, Real-Time Inventory Management Service, Transportation Tracking Service. **Logistics/Distribution:** Product Location Information Monitoring Service, Warehouse Management Service, Procurement Management Service, and Logistics Tracking Service.
Construction / Facility Management	Safety Management Service, Public Facility Control Service, Building Management Service, Access Control Service, Facility Monitoring Service, Road / Bridge Condition Monitoring Service
Occupational Safety / Environment / Disaster / Disaster	Water Quality Management, Meteorological Information Collection and Provision, Food Waste Management, Smart Environmental Information Provision, and Disaster Monitoring Service
National Defense	Reserve Forces Management Services, Battlefield Surveillance and Unit Protection Services, Firearms and Ammunition Management Services, Terrorism Detection Services, Fiber Optics uniforms
Production	Production, Process Control Services, Machine Diagnostic Services, Factory Automation Services, and Time Monitoring Services for Manufacturing Facilities.
Smart Home	Home Appliance Remote Control Service, Home CCTV Service, Smart Door Lock Service, Artificial Intelligence Speaker.
Smart Grid	Communication Networks, Cybersecurity, Distributed Energy Resources, Distribution Grid Management Energy Efficiency, Wide-Area Monitoring, Advanced Metering Infrastructure, Long-Term Evolution.
Finance	IoT-Based Real Estate Collateral Management Service, Beacon-Based Financial Product Guidance and Customer Service.
Aerospace / Space	Aircraft Interior Monitoring Service and Real-Time Remote Aircraft Inspection Service.
Ship-Building / Ship	Vessel Location Monitoring, Vessel Remote Inspection Service, and Vessel Internal Monitoring.
Energy management and meter reading	**Energy Management:** Edge Monitoring Service, Building Energy Management Service, Power/Power Monitoring and Control Service, and Renewable Energy Management Service. **Meter reading:** remote meter reading services such as electricity, gas, and water, and real-time billing services
Education	Smart Attendance Management Service, Educational Equipment Management Service, and Smart Library Service.

Fig. 4 Applications of IoT along with their services

IV. SMART GRID

Electrical power is defined as “The rate of change of energy with respect to the time at which electrical energy is transferred by an electric circuit.” The SI unit of the power we measure is Watt (W) [11].

$$\text{Electrical Power} = \text{work done in an electrical current/time}$$
$$P=VI/t=VI=IR^2$$
$$=V^2/R$$

Generally, power is transferred/generated by the generator on a large scale of electrical power, but on a small scale, it also transfers with the help of the batteries. But in daily life, the unit of power is generally taken in megawatts, and electric power is measured with the help of the Wattmeter. The amount of the power transfers by a battery or generator for t time. When they are multiplied together, it is known as electrical energy. In the DC circuit, the load is only resistors. So there, we measure only the Power (or active Power).

But in the case of the AC, the capacitor inductor comes into the picture. Due to these elements, they required electromagnetic energy for their working to the storage capacity of the wire. So, another power comes into the picture, known as Reactive Power. It is not actual power, but it is a supporting power. These whole concepts of the power in the AC system come into the consideration of the Complex power. Now we will discuss the concept of complex power.

A. Complex Power

In the above discussions only thing that when V and I are constantly in the dc concerning the time. But as it is known that they continuously change with time. Both of them are a continuous function of time, and also, they are not in the same phase, i.e., Out of both, one is lead concerning another or vice versa. So, they have phase differences. The reason behind this is the type of load we connected in the system [13].

$$P=V(t)I(t)$$

This is known as instantaneous power, which is a function of the time from this equation; we can easily find the power at any instant. By suppressing the time factor, we converted the expression of the voltage and current into a complex domain.

$$V=Ve^{j\omega t}$$

$$I=Ie^{j\omega t}$$

And by observation, we conclude that

$$S=VI^*$$

Where V=phasor voltage

I=phasor current

*=complex conjugate

S=complex power

From the expression, we conclude that S is completely a complex quantity, from that expression, we can write it as

$$S=P+jQ$$

here

P is known as active power, and Q is known as reactive power.

$$P=VI\cos\Phi$$

$$Q=VI\sin\Phi$$

Where Φ is the angle between current and voltage.

V is r.m.s. value of the voltage

I is r.m.s. value of the current

P is also known as active power /useful power /average power /power or power absorbed or delivered by the circuit or element. Q is also known as reactive power /lagging VAR absorb by the circuit or circuit element (VAR). Q is generally two types: - lagging power and leading power. The type of Q depends upon the type of the load, but in the expression, we generally take the legging power because our entire power system is lagging in nature.

B. Convention of Power Flow

It is important to study the sign convention of the power flow. The sign of power depends on the signs of voltage and direction of the current, which means either it leaves from the positive sign or enters. Based on these two things by keeping in mind, it can be easily calculated that either power is absorbing or delivered [14].

C. Here Complex Power is Absorbed

Figure 5 represents the power absorbing circuit, from it can be concluded that;

If $P>0$: circuit absorbs active power

If $P<0$:-circuit delivers active power

$Q>0$:-circuit absorbs reactive power /lagging VAR/lagging

Current or circuit delivers leading VAR/leading current.

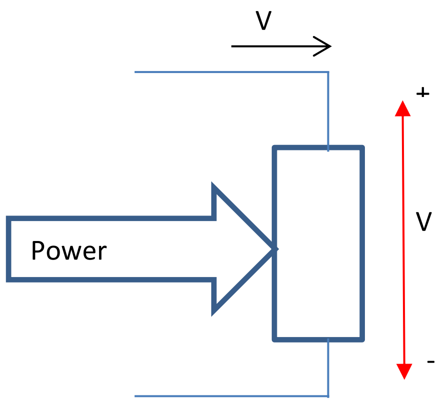

Fig. 5 Power Absorbing circuit

$Q<0$circuit delivers reactive power /lagging VAR/lagging-current, or circuit absorb leading VAR/leading current

a) Complex Power Delivers by the Circuit or Circuit Element

Figure 6 represents the power absorbing circuit

$$S=VI^*$$

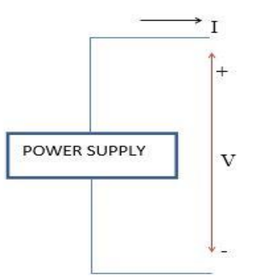

Fig. 6 Power Delivering Circuit

Table 1. Power Absorb -Delivery System		
Sr. No	**Parameter**	**Action**
1.	P	active power delivers by the circuit
2.	Q	reactive power delivers by the circuit
3.	If P>0	circuit delivers active power
4.	If P<0	circuit absorbs active power
5.	If Q>0	circuit delivers reactive power
6.	If Q<0	circuit absorbs reactive power

D. Active Power

The active power is also known as the average power. It is the product of the r.m.s value of the voltage and current and cos of the angle between them.

$$P=VI\cos\Phi$$

Its SI unit is the watt; for higher power applications, it is also measured in the KW. The instrument used for the measurement of the active power is a wattmeter.

E. Reactive Power

The Reactive power is also known as supporting power. It is the difference between apparent power and active power. Also, it is defined as the product of the voltage and current and sin of the angle between them.

$$P=VI\sin\Phi$$

Its SI unit is VAR.

- The main reason is that the inductance of the system requires magnetic energy to produce flux. Due to that effect, the concept of reactive power comes into the picture [14].
- Most of the equipment used in the industries consumes reactive power. These devices are electric motors, transformers, chokes, converters, arc furnaces, and power electronics devices.
- In an inductive circuit, the reactive power is related to the frequency and the peak value of the energy stored periodically in the form of magnetic and electric fields of the circuit elements.

a) Reactive power in the case of the inductor

$$Q=VI\sin\Phi$$

$$\Phi=90^\circ \text{ \{because the angle between V and I\}}$$

$$\text{So } Q_{ind}=VI \qquad I=\frac{V^2}{\omega l}$$

$$Q=\frac{V^2}{\omega l}$$

So, from here, it is concluded that reactive power is inversely proportional to the frequency in the case of the ideal inductor.

1) Reactive power for capacitor

$$Q_c=VI\sin\Phi=VI$$

$$I=V/1/\omega C$$

$$=V^2\omega C$$

So from here, it is concluded that reactive power is directly proportional to the frequency in the case of the ideal capacitor.

2) Apparent Power

It is defined as the product of the r.m.s. Value of the voltage and current. Its unit is VA. It is represented by S [13].

$$S=VI$$

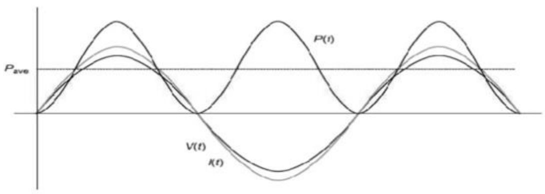

Fig. 7 Power Waveform in Resistor

From figure 7, It may be seen that the Power is positive for every cycle. So, from here, conclude that Power is always positive, i.e., Power is constantly consumed by resistors.

$$\text{So, } P= V(t)\ I(t)$$

&

$$P_{avg} = V_{rms}\ I_{rms}$$

$$\text{Also, } S=P+jQ$$

the magnitude of the complex power is also known as apparent power.

$$|S|^2 =P^2+Q^2$$

$$Q=\sqrt{(S^2-P^2)}$$

3) Instantaneous Power

The instantaneous power is defined as the product of the voltage and current in the time domain.

$$P= V(t)I(t)$$

This type of power is not considered too much in the power analysis. So generally, we don't study instantaneous power in modern power analysis.

Now it is discussed to the instantaneous power with the help of each primary electrical system component, e.g., Resistor, capacitor, and inductor.

i) Resistor

In the case of the Resistor, voltage and current are in the same phase, so there will be no phase difference between them.

The frequency of the Power is two times the original supply.

$$f_p=2\times f_{supply}$$

$$P_{+ve} \neq P_{-ve}$$

But in the case of the pure inductor. So in the pure inductive load (or ideal) inductor, the net power consumed (active) is zero, as shown in figure 8.

$$P_{+ve}=P_{-ve}$$

$$f_p=2\times f_{supply}$$

Or

$$T_p=\frac{Tsupply}{2}$$

And also, the frequency of the power is two times the original supply

ii) Capacitor

In the case of the capacitor, voltage waveforms are leg the current by same phase angle Φ

Now it can be discussing the power in each cycle.

In some regions, P is positive, and in some cases, P is negative.

$$P_{+ve}\neq P_{-ve}$$

But in the case of the pure capacitor

$$P_{+ve}=P_{-ve}$$

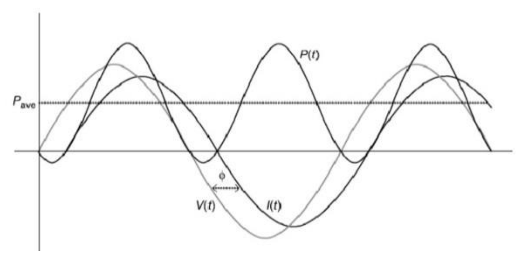

Fig. 9 Power Waveform in Inductor

So, in the pure capacitor load (or ideal) capacitor, the net power consumed (active) is zero, as shown in figure 9.

$$f_p=2\times f_{supply}$$

OR

$$T_p=\frac{Tsupply}{2}$$

And also, the frequency of the power is two times the original supply.

V. POWER FLOW ANALYSIS

It is the fundamental study of power to determine the voltage at each node. By using this analysis, determining the voltage for busload in terms of magnitude and angle. Which is used to calculate the power factor and losses.

A. Loss Calculation

Since the loss calculated here is the loss as a circuit (as well as the efficiency).

$$\boldsymbol{Loss(W) = Output\ Power(W) * \left(\frac{1 - Efficiency}{Efficiency}\right)}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} A_{ij}(P_iP_j + Q_iQ_j) + B_{ij}(Q_iP_i - Q_jP_j)$$

$$A_{ij} = \frac{R_{ij}}{V_iV_j} Cos(\delta_i - \delta_j),$$

$$B_{ij} = \frac{R_{ij}}{V_iV_j} Sin(\delta_i - \delta_j)$$

$$\begin{Bmatrix} R - Resistance, \\ V - Voltage, \\ \delta - \ angle\ at\ Correspondence\ Buses \end{Bmatrix}$$

B. Branch Loss

The loss of the power system must be calculated separately regardless of which method is used, so it is not significantly different from calculating individually.

C. Total System Losses

Finally, round off decimals in calculations by default. As for the number of digits, it is recommended to use the valid (affected) number of digits to consider the total power. This is to prevent problems caused by errors, and caution is required in the case of negative factors such as loss and heat generation. However, the margin should be fully considered when making a decision.

a) Relation between Voltage and reactive power on the Transmission-line

Let's assume a general transmission system with a source of complex power, as shown in fig.5.1.

The relation for reactive power and terminal voltage (load bus and source) is given by [16]

Q_r=Receiving reactive power at the load bus

Q_s=supply reactive power

By using the basic concepts of the power, drive a formula for the reactive power in relation with voltages at both ends, and line reactance is given by

$$Q_r=|V_sV_r/X_L|\cos\delta-|V_r^2/X_L|$$

$$V_r^2-|V_sV_r|\cos\delta+X_LQ_r=0$$

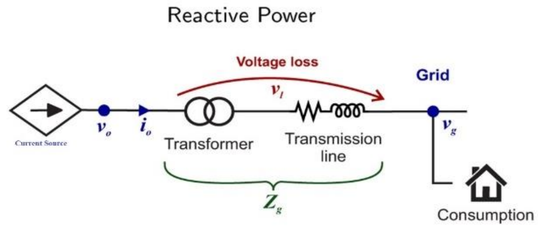

Fig. 10 Reactive Power

Compare with the general quadratic equation

$$aX^2+bX+c = 0$$

$$V_r = \frac{Vs*\cos 2\delta \pm \sqrt{V_S*2*Cos\ 2\delta - 4X_LQ_r}}{2}$$

Let's assume δ is very small δ=0 so $\cos\delta = 1$

$$V_r = \frac{V_S \pm \sqrt{{V_S}^2 - 4X_LQ_r}}{2}$$

$Q_r=Q_1-Q_2$=net reactive at the load bus

Q_1=reactive power demand by the load

Q_2=reactive power supply by the source

By ignoring the negative sign in equation (1)

Table 2: Case and parameters

Case No	Parameters
1	If $Q_r=0 \Rightarrow Q_1=Q_2$ $V_r=V_s \Rightarrow V_{reg}=0$
2	If $Q_r>0 \Rightarrow Q_1>Q_2$ $V_r<V_s \Rightarrow$ positive regulation Peak load time
3	If $Q_r<0 \Rightarrow Q_1<Q_2$ $V_r>V_s \Rightarrow V_{reg}$ is negative

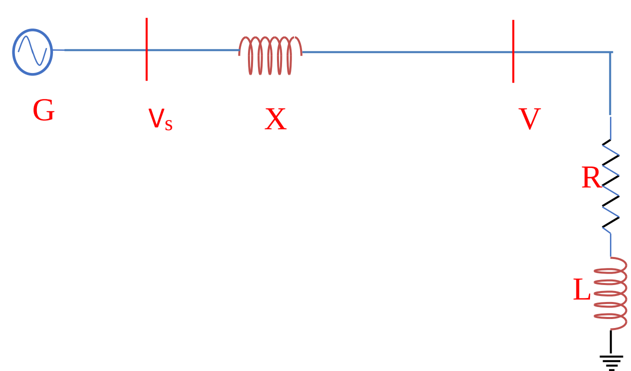

Fig. 11 Circuit Diagram without Compensation

By analysis, we observe that

ΔV άΔQ

ΔV άQ_1-Q_2

V_1-V_2ά Q_1-Q_2

If Q1 is increasing means demand increases. Also, ΔQ to increase ΔV for same proportion, the load voltage decrease V2 decrease. This is the main problem with reactive power; whenever load demand increases, there is a voltage dip problem faced by all the consumers. That's why various methods compensate for the reactive power demand.

VI. POWER FACTOR

By means help you understand, I will briefly summarize the meaning of power factor, improvement methods, and effects by briefly arranging apparent power, active power, and reactive power. An AC circuit is the product of the RMS value of voltage and the RMS value of current. In other words, when it is numerically possible to do 1100W of work when supplying 220V of voltage and 5A of current, the ability of that 1100W is apparent power. Power usefully used for loads in AC circuits. In an AC circuit, the phase angle of AC is different due to the electrical resistance of the line and the components of capacitor and coil of the load resistance. This is called the power factor and is called cos∅.
Since we know that [5]

S=P+jQ

The argument of the complex power equation is

$$\emptyset=\tan^{-1}\frac{Q}{P}$$

Here in the power system, "Φ" is the power factor angle, and cosΦ is the power factor. The power factor gives how much apparent power is converted into active power. Power factor is defined as the degree to which a given load is composed with pure resistive load i. e.

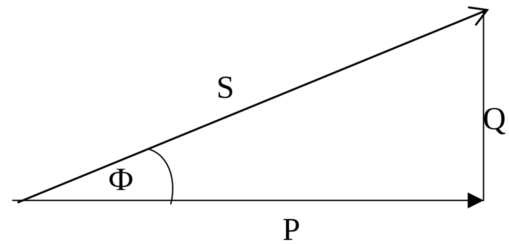

Fig. 12 Power Factor from Triangle

How much percentage of the apparent power is converted into active power? The value of the power factor is a maximum one only in the case of the pure resistive load. Its high value is preferred Power Factor =Active Power /Apparent Power from figure 11; it can be concluded that

$$\cos\emptyset = \frac{P}{S}$$

The complex power equation is

$$S=P+jQ$$

$$|s| = \sqrt{P^2+Q^2}$$

$$\cos\emptyset = Power\ Factor = \frac{P}{S} = |s| = \sqrt{P^2+Q^2}$$

VII. CLASSIFICATION OF LOAD

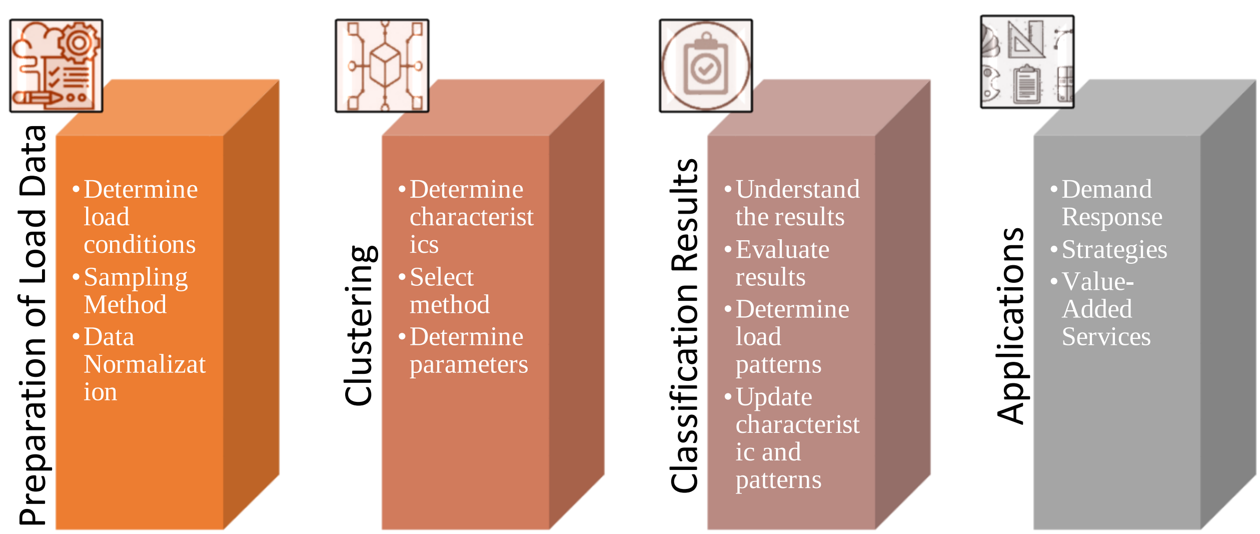

Fig. 13 Load Classification

VIII. TOOLS & TECHNIQUES FOR IMPROVE POWER FACTOR OF SMART GRID

In general, electrical equipment manufactured using motor coils, etc., is an inductive load and has a low power factor. In order to improve the Performance of Smart Grid, there are various types of methods and tools have been used. Some of them are listed below:

- Advanced Metering Infrastructure
- Modern Monitoring Devices
- Information and Communication Technology
- Computational Intelligence
- Advanced Control Methods
- Active Demand-Side Management and Demand Response
- Multi-Agent Technology
- Internet of Things
- Smart Appliances

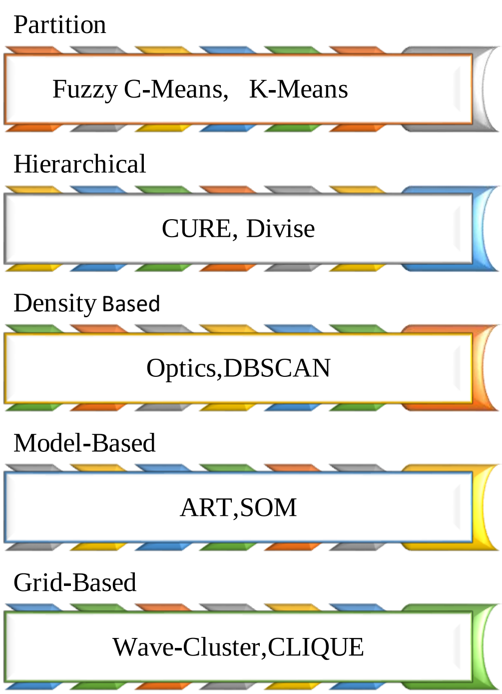

Fig. 14 Clustering Methods

IX. CONCLUSION

The smart grid concept emerged as the core of green energy industry innovation that minimizes greenhouse gas emissions. Smart grid is a next-generation power grid technology that improves the power grid's efficiency, reliability, and safety by applying information and communication technology to the existing power grid and optimizes energy efficiency by distributing power generation and consumption information in both directions in real-time. Currently, the United States is promoting smart grid technology competitively, activating the use of new and renewable energy in Europe, and efficient energy management in other developed countries. This study has presented a vision of clean energy green energy as a national development in the future.

REFERENCES

[1] Naman et al., Load and their schemes Analysis of Distribution Network Using Linear Data Structure, M.Tech thesis Y.I.T. Jaipur, (2016).

[2] Sinan Küfeoğlu, Michael Pollitt & Karim Anaya, Electric Power Distribution in the World: Today and Tomorrow, https://www.researchgate.net/publication/327057595

[3] Abdullah Mahmoudi, Seyed Hossein Hosseinian, Direct Solution of Distribution System Load Flow Using Forward/Backward Sweep.https://www.researchgate.net/publication/261155665

[4] M. Mahesh Kumar, A Study of Reactive Power Compensation in Power System and Its Compensation Techniques Special Issue NCRTEEFOSS-2016 IJEST

[5] Samarjit Bhattacharyya, Dr. A Choudhury, Prof H.R. Jariwala, Case Study On Power Factor Improvement ISSN: 0975-5462 3 (12)(2011)

[6] A. Rabiee, H. A. Shayanfar and N. Amjady, A New Framework for Reactive Power Market Considering Power System Security Iranian Journal of Electrical & Electronic Engineering, 5(3)(2016)

[7] Kumar, N., & Singh, G. (2019). Energy Efficient Load Optimization Techniques for Smart Grid with Futuristic Ideas. International Journal of Engineering and Advanced Technology, 9(1) (2019) 4327–4331. https://doi.org/10.35940/ijeat.a1778.109119.

[8] Climate Group.: The and GeSI, SMART 2020: Enabling the Low Carbon Economy in the Information Age (2008),

[9] Benjamin Barán, Multi-objective Reactive Power Compensation, 0-7803-7287-5/01/IEEE

[10] Wenjuan Zhang, Review of Reactive Power Planning: Objectives, Constraints, and Algorithms, IEEE TRANSACTIONS ON POWER SYSTEMS, 22(4)(2007).

[11] B.L.Theraja, A.K.Theraja, A Textbook of Electrical Technology, S. CHAND Publication

[12] Prasad K., Sahoo N. C., Chaturvedi A. and Ranjan R, A Simple Approach in Branch Current Computation In Load Flow Analysis Of Radial Distribution Systems, International Journal for Electrical Engineering Education, 44(1)(2007)1.

[13] D.Roy Choudhury, Network and System New Age Publication

[14] Jakub Kepka, Reactive Power Compensation Master Thesis, Wroclam University of Technology, (2017)

[15] N. Kumar and G. Singh, A Novel Algorithm to Improve the Power Quality for the Smart Grid and Integration with the Optimization Framework. International Journal of Engineering Trends and Technology, 69(9)272-280. DOI: https://ijettjournal.org/archive/ijett-v69i9p233

[16] European Commission: European SmartGrids Technology Platform: Vision and Strategy for Europes Electricity Networks of the Future. Brussels (2006).

[17] http://www.theclimategroup.org/assets/resources/publications/Smart2020Report.pdf

[18] J. M. Guerrero, P. C. Loh, T.-L. Lee, and M. Chandorkar, Advanced control architectures for intelligent microgrids—Part II: Power quality, energy storage, and AC/DC microgrids, IEEE Transactions on Industrial Electronics, 60,(2013)1263-1270.

[19] S. Y. M. Mousavi, A. Jalilian, M. Savaghebi, and J. M. G. GE, Autonomous Control of Current and Voltage Controlled DG Interface Inverters for Reactive Power Sharing and Harmonics Compensation in Islanded Microgrids, IEEE Transactions on Power Electronics, 1(1) 2018.

[20] Atkinson, R., Castro, D.: Digital Quality of Life Understanding the Personal & Social Benefits of the Information Technology Revolution. In: The Information Technology and Innovation Foundation, Washington DC (2008)

[21] Department of Energy: The smart Grid – an introduction (2008)

[22] Tsoukalas, L.H., Gao, R.: From Smart Grids to an Energy Internet: Assumptions, Architectures and Requirements. In: DRTP, (2008) 94–98

[23] LeMay, M., Nelli, R., Gross, G., Gunter, C. A.: An Integrated Architecture for Demand Response Communications and Control. In: Proceedings of the 41st Hawaii International Conference on System Sciences, (2008)1–10.
[24] Singh, R. & N. S. Gill. Use of IoT and Machine Learning for Efficient Power Management Through Smart Grid: A Review | International Journal of Advanced Science and Technology. (2020). http://sersc.org/journals/index.php/IJAST/article/view/30681
[25] Singh, R., Gill, N. S. & Gulia P. (2021). A Systematic Review of Security in Smart Grid Infrastructure Journal of Theoretical and Applied Information Technology. 99(23)(2021). ISSN: 1992-8645 and E-ISSN: 1817-3195.
[26] Miller, J.: The Smart Grid How Do We Get There? Smart Grid Ne (2008).
[27] Smart grid and power quality issues. (n.d.). ScienceDirect.com | Science, health and medical journals, full-text articles and books. https://www.sciencedirect.com/science/article/pii/B978008102493500 0108
[28] (n.d.). Springer. https://link.springer.com/content/pdf/10.1007/978-3-642-19322-4_15.pdf
[29] C. H. Da Silva, R. Pereira, L. Silva, G. Lambert-Torres, R. Gonzatti, S. Ferreira, et al., Smart impedance: Expanding the active hybrid series power filter concept, in IECON 2012-38th Annual Conference on IEEE Industrial Electronics Society, (2012) 1416-1421.
[30] A. Baloi, A. Pana, and F. Molnar-Matei, Contributions on harmonic impedance monitoring in smart grids using virtual instruments, in Innovative Smart Grid Technologies (ISGT Europe), 2nd IEEE PES International Conference and Exhibition on, (2011)1-5.
[31] R. C. Dugan, M. F. McGranaghan, and H. W. Beaty, Electrical power systems quality, New York, NY: McGraw-Hill,| (1) (1996).
[32] K. T. Mok, M. Wang, S. C. Tan, and S. Y. Hui, DC Electric Springs - A New Technology for Stabilizing DC Power Distribution Systems, IEEE Transactions on Power Electronics, (1)1(2016).
[33] J. He, Y. W. Li, F. Blaabjerg, and X. Wang, Active harmonic filtering using current-controlled, grid-connected DG units with closed-loop power control, Power Electronics, IEEE Transactions on, (29) (2014) 642-653.
[34] J. C. Vasquez, J. M. Guerrero, A. Luna, P. Rodríguez, and R. Teodorescu, Adaptive droop control applied to voltage-source inverters operating in grid-connected and islanded modes, Industrial Electronics, IEEE Transactions on, (56)(2009)4088-4096.
[35] J. M. Guerrero, M. Chandorkar, T.-L. Lee, and P. C. Loh, Advanced control architectures for intelligent microgrids, part I: decentralized and hierarchical control, IEEE Transactions on Industrial Electronics, 60(2013)1254-1262.
[36] L. Meng, F. Tang, M. Savaghebi, J. C. Vasquez, and J. M. Guerrero, Tertiary control of voltage unbalance compensation for optimal power quality in islanded microgrids, IEEE Transactions on Energy Conversion, 29(2014)802-815.
[37] Application of IoT and available at: https://ittrue.tistory.com/17 last accessed on (2021)
[38] Y. Naderi, S. H. Hosseini, S. G. Zadeh, B. Mohammadi-Ivatloo, M. Savaghebi, and J. M. Guerrero, An optimized direct control method applied to the multilevel inverter for microgrid power quality enhancement, International Journal of Electrical Power & Energy Systems, 107(2019)496-506.
[39] Agarwal, V., & Tsoukalas, L. H. Smart Grids: Importance of Power Quality. Energy-Efficient Computing and Networking, (2011).136–143. doi:10.1007/978-3-642-19322-4_15.
[40] Retrieved from: https://encryptedtbn0.gstatic.com/images?q=tbn:ANd9GcSn12XQJASqwpwNnqgXL1yk7vHr2Ebh7qkKXQ&usqp=CAU Last accessed on (2021).