Latest trends and their adoptions in electrical power systems - an industrial perspective

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Article Info

ABSTRACT

Electricity is a vital part in every day's life and is one of the greatest gifts given by science to the mankind. It has provided all the comfort to the human beings right from lighting to large machines through computers and amusement equipment. Electrical power system (EPS) is moving fast into new horizons and making the entire world dynamic just like the speed of electron. In this paper, the latest trends that are happening globally in electrical power systems are highlighted. The major changes that are taking place in all applicable fields such renewable energy, especially photovoltaics (PV), smart grids (SG), ulta high voltage (UHV) transmission, distributed generation, micro grids, de-regulation and e-mobility are reviewed for updating all the stake holders of it. Also, the adoption of latest technologies such as internet of things (IoT) and artificial intelligence (AI) are briefly mentioned.

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1. INTRODUCTION

Electricity is greatly serving the mankind right from health sector to transportation through lighting and communication. Electrical power system is at the forefront of today's exciting innovations by breaking all the barriers. The recent innovations in solar photovoltaics (PV), alternating current and direct current (AC and DC) transmission and e-mobility have led to more energy efficient equipment with better control techniques. Global electricity demand rose by 5.54% (i.e. a total of 54,833 TWh) in 2021 over the preceding year, as shown in Figure 1, nearly twice as fast as overall energy demand which is mostly taken care by renewables @ 38% of total demand [1]. In the same time, developing countries like India, the electrical energy demand was 3,394 TWh, an 8.75% rise from previous year. The total installed capacity of electrical power in India as in March 2022 is 392 GW from all the sources in which solar power is @ 13.52%. The Indian grid electricity demand is expected to be around 2040 to 15,820 TWh by 2040 [2]. Government of India has made an ambitious plan of 175 GW (out of which 100 GW from Solar) from renewables by 2022. To meet this requirement, huge investments in power sector are required with participation from both public and private. Also, lot of work is being done in power transmission side to maintain balance among all the geographical regions of country. In addition to massive financial investments, improving the infrastructure and utilising the latest technologies is essential including encouragement of research work in electrical and electronic engineering fields. Some of the most exciting new ideas in the recent past and their possible application in electrical power system (EPS) are highlighted in sub-sequent sections.
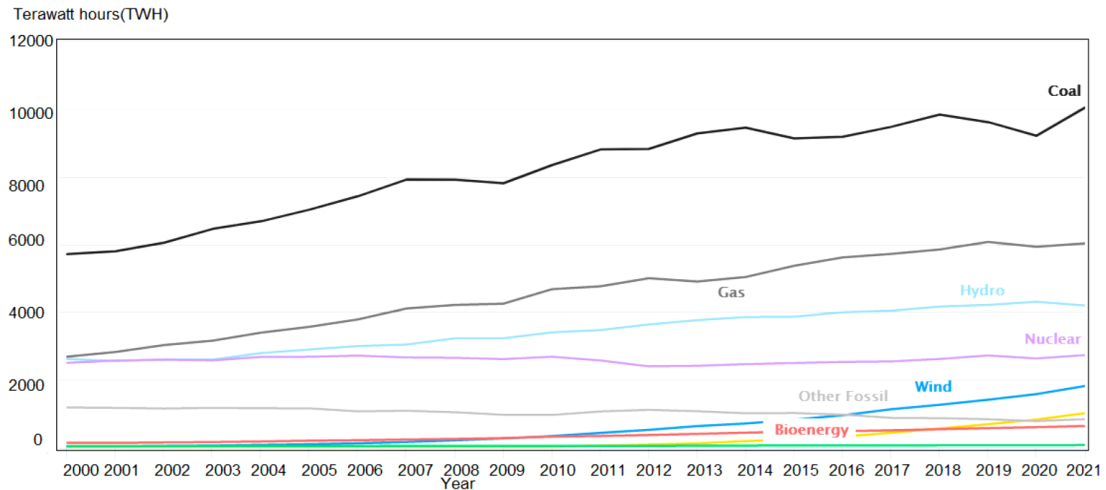
Figure 1. Source-wise World electricity generation

2. SOLAR PHTO-VOLTAICS

The maximum efficiency of solar photo-voltaic (SPV) crystalline modules as on date is around 18%. A lot of work is being done by different innovations. One of such innovations is use of both sides of PV modules which are called bi-facial modules as shown in Figure 2 [3], [4]. Bifacial modules harness sun light from both front and rear sides of the PV panel. Incase of the traditional or mostly available PV modules in market as on date are mono-facial i.e., they work at front side only. Some are designing back framed and others as frameless. These modules have contacts and bus bars on both front and back sides. The bifacial PV modules stop any reflected light from reaching the rear-side of the PV cells. This technique helps the bifacial PV modules in performing better than mono facial PV modules and improves the cell efficiency by 5 to 10%. It is being adopted in most of the PV applications now. In case of roof-top mounting, the output can further improve by painting the floor with white paint-module-integrated AC Inverters.
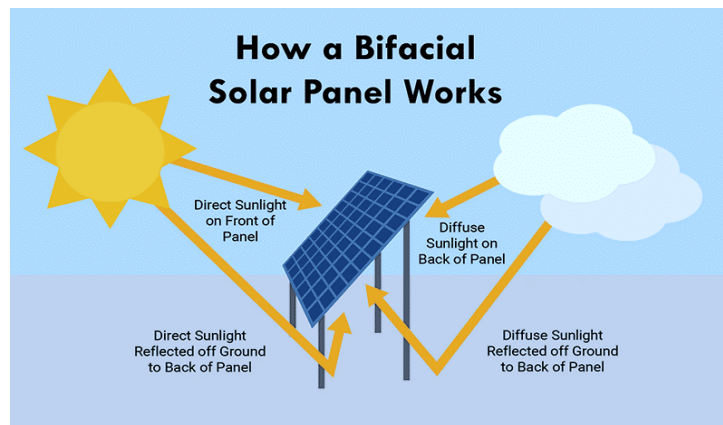

Figure 2. Bi-facial modules

Now the latest trend is integration of all the electronics i.e., mainly the inverters to the rear side of PV modules. Such type of PV modules built-in with inverters separately connected to the power grid. This arrangement increases the power output of PV modules due to individual PV module-level maximum power point tracking (MPPT). This technique also helps in reducing the installation costs and space savings. Inverters with reactive power compensation have also evolved in the PV market. These are known as smart inverters which can work as stand-alone power generation facility without any grid support. Multi-material solar cells, known as multi junction devices with different band gaps that cover a range of the solar spectrum and can achieve the highest efficiency of around 30% [5].

Now the trend in roof top is to use PV modules which encapsulate the roof i.e, top of buildings with solar-skin in which a thin film, that is particularly glazed with ultra-robust visuals and unified with best efficient PV panels. In addition, working as ceiling, it generates power @ 10 KW for a 2000 Sq Ft roof. It is claimed to be more durable than the standard roof products. It is designed to balance with typical roof aesthetics without any noticeable difference on roof. In addition to PVs, lots of research is going on renewable energy (RE) fields, for a energy balance [6]. But there are certain issues such as integration effects, fault currents [7], reactive power management [8] and protection issues [9] which are being dealt carefully by the end users. After PV, next credit goes to wind energy with further improvements in wind turbine, induction generator and power electronics. Also, there is some improvement in other REs such as geothermal and tidal energy.

3.   UHV TRANSMISSION

Continuous efforts are in place globally on transmission of electrical power at higher and higher voltage levels sucha s ulta high voltage (UHV) to reap the benefit of HV and UHV transmissions. In case AC transmission, the changes that took place since inception are shown in Figure 3. China energized its first UHV AC demonstration line - a 650 km, 1,000 kV in 2009. In case of DC transmission, India has constructed a + 800 kV DC line between Champa and Kurukshetra in 2017 (for transfer of 3 GW power). China is developing a 1,100 kV UHVDC line developed for 10 GW power. The brief details about the latest 1,100 kV transmission is highlighted here under [10]:

− Rated power is fit for a maximum of 12,000 MW or so.
− Expected power transmission distance covers around 1,864 miles or 3,000 km.
− Each transformer used in the system is around 105 feet long and weiht is around 800 T.
− The UHVDC links are based on line commuted converter technology (LCC) in conjunction with overhead transmission line. Also, a 1,100 kV ultra high voltage direct current (UHV DC) system can intensify the power transmission capability to 12 giga watts (GW) which is 50% higher than that of existing 800 kV HVDC systems.
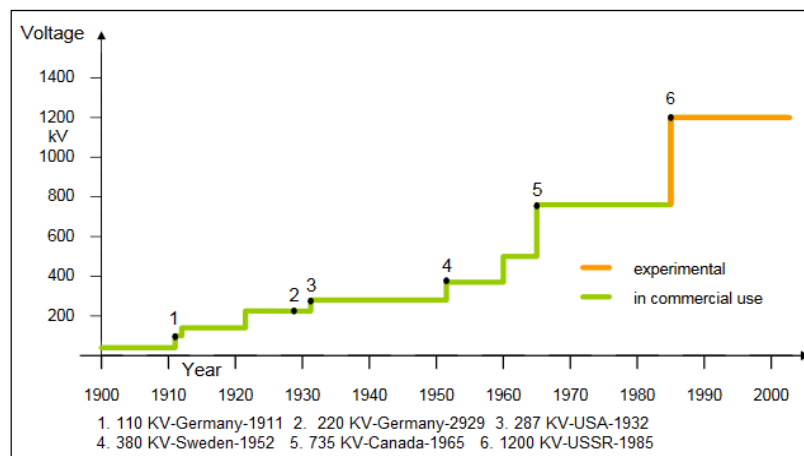

Figure 3. Development of AC transmission voltages over years

4.   SMART AND MICRO GRIDS

Smart grid (SG) and micro grid (MG) are not technologies but combination of several latest techniques suchas internet of things (IoT), artificial intelligence and De-regulation. As per european union (EU) smart grids technology platform, the concept of smart grids is explained as an effiecient network of power generators and its consumers with an intension of delivering sustainable and reliable electrical enrgy [11]. Also, a MG is defined as "a locally formed mini electrical power grid which will works as an independent entity or in collaboration with similar grids" [12]. These SG and MG are being supported by the latest bright devices such as smart meters and cutting-edge communications. These two grids together can work as an instrument for accomplishing the world leaders expected goals in the areas of energy and its security. The benefits that can be given by SG are pictorially shown in Figure 4. Most of industries are trying to adopt these SG and MGs along with distributed generation (DG) by overcoming certain hurdles such as reactive power and harmonics including balancing of their cogeneration units [13].
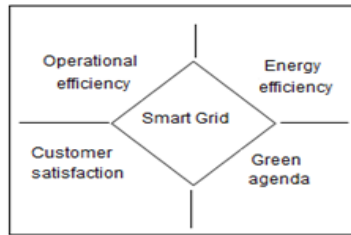
Figure 4. Benefits of SG

5.   RETROFITS AND RENOVATIONS

In any organisation or establishment, the availability of equipment is more with No-2-less (N2L) brekdowns when they are instralled newly. But with the ageing of equipment, the brekdowns starts coming up with increased maintenance costs and associated reduced availability. Also, the power quality issues such as voltage and frequency fluctuations, and load traumas, will accelerate the ageing process and causes more and more equipment wear and tear. Here the available mitigation techniques are run-to-failure (R2F) timely replacement of age-old apparatus. For technically obsolete apparatus or components; the finest choice is to retrofit them with technologically advanced components or equipment by exploiting the standing space and other healthy-hardware [14]. This type of retrofits will reduce the failures, maintenance costs and improved availability of equipment. Such type of retrofits can be done at user area to spread the lifecycle of equipment. An example of retrofitting of electromagnetic protection relay with latest digital relay is shown in Figure 5.

Figure 5. Retrofitting of relay

6.   POWER DE-REGULATION

Electriccal trading through power exchanges like share markt, is introduced in many of the global centers. In developing countries like India too have introduced two power exchanges such as Indian energy exchange as dipicted in Figure 6 [15] and power exchange of India limited. These power exchanges are running under the directins and monitoring of central electricity regulation commission (CERC). With the entry of private operator in power sector, there is an increase in transparency, and competition in the market. The salinet points in open power exchange includes a platform for trading of electrical energy, encouraged competition, transparent on-line trading and homogenous indentures. Significant benefits of power industry deregulation [16], [17] would include reduced electrical costs, wide competitive options in front of energy users or customers, user-based services and also provides path for further modernizations.

	DAM	TAM	REC

22 Apr 2022	Term-Ahead Market		
	Purc. Bids (MWh)	Sell Bids (MWh)	Traded (MWh)*
DAC	6343.5	6129.5	4973.5
Intra Day	5397	392.5	352.5
Daily	205488	129552	121488
Weekly	--	--	--
	*scheduled volume may vary		

Figure 6. IEX model

7.   CHEMICAL EARTHING

Now the electrical safety system is going for Chemical earth pits [18] in place of traditional galvanized iron (GI) Rod based earth pits, as shown in Figure 7. Chemical earthing gives advantages such as zero corrosion, less space requirement and almost maintenance free with increased life of 25 years. Even though it is costly compared with GI model, industries are adopting due to its added advantages as above.
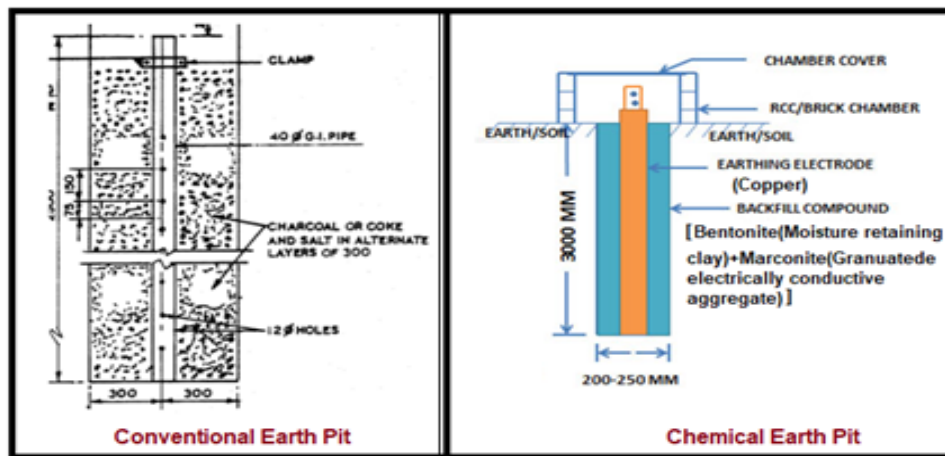

Figure 7. GI and chemical earth pit

8.   CURRENT MAINTENANCE PRACTICES

Against the traditional scheduled maintenance (maint.), now the trend is towards condition-based maintenance (CBM) [19]. For small equipment, the initial maint. check will e Listen the sound, look for abnormalities, and feel the abnormality by touching the body for temperature (LLF). For further checks various techniques such as current signature analysis (CSA), thermography, vibration analysis (VA), and insulation resistance (IR) measurement and leakage current recording. Based on these tests, suitable action will be taken, which will improve the availability of equipment. with reduced inventory and manpower cost. A sound maint technique suitable for a particular industry or establishment is to be adopted. Here the maintenance is made reliant on the present state of apparatus. The ailment of the any apparatus is patterned through pictorial or visual examinations and based on the data collected with suitable tackles and tools. The expected advantages of adoption of CBM are condensed number of unintended breakdowns, time saving, improved equipment availability and reliability, worker safety in addition to improved apparatus performance.

9.   E-MOBILITY

To achieve the six zeros emission, energy, accidents, congestion, costs and empty, in electric vehicles (EV) [20], [21], lot of work is on cards for optimum design of power train, fuel cell incorporation, higher energy density batteries, and new fast charging techniques. It is expected that the future charging will be through a battery swap technique like a domestic LPG cylinder change. Also, Lithium-air battery [22] with 1,000 Wh/kg energy density is expected in near future. Also, research is going on for better wireless charging of EVs. Future charging technologies will include Wireless charging and smart charging.

10.   ARTIFICIAL INTELLIGENCE

Evolution of artificial intelligence techniques brought tremendous change in industrial sector especially in electrical engineering field. It is helping the EPS in the fields of forecasting [23], maintenance practices, optimal allocation of resources [24], supply-demand balance, load scheduling, inventory management and price-scheduling in day-ahead markets. Machine learning find wider applications in distribution system, voltage regulation, adaptive protection system [25] and storage systems [26]. Deep learning techniques are being widely used in classifications and image identification which is widely used in maintenance management especially in thermography.

11. CONCLUSION

The nature of use of electricity is taking many shapes at end users point and the human life will almost come to standstill without it. It is moving incessantly with continuous research and with the help of inteliigent electronic devices (IED) and software tools especially artificial intelligence (AI) and machine learning (ML). The technology that thought as new today is becoming obsolete by tomorrow. The electrical engineering filed is spreading all the places with its wide uses and advancements. In this work has highlighted some of the latest trends in EPS and their adoption. The future work can be done in full utilization of artificial intelligence techniques in EPS.

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