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DRONE APPLICATION FOR THE INDIAN POWER SECTOR

South Asia Regional Energy Partnership
February 2023

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GOVERNMENT OF INDIA
MINISTRY OF POWER

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The U.S. Agency for International Development's India Mission (USAID/India) and Power Finance Corporation (PFC) pursue the common objectives of accelerating utility modernization, improving the financial and operational performance of the state utilities, and encouraging the adoption of new technology solutions.

USAID's five-year flagship regional program, the South Asia Regional Energy Partnership (SAREP), supports PFC with technical assistance and knowledge inputs to facilitate the transformation of utilities. To achieve the above, SAREP has developed this whitepaper to create awareness and promote faster adoption of advanced technologies by the power sector in India.

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FOREWORD

Providing 24x7 reliable, affordable, and quality power with enhanced consumer satisfaction is critical to accelerated economic growth and a key priority for the Government of India. Operationally efficient and financially viable utilities are essential in achieving this goal.

2. Towards this effort, Ministry of Power's flagship Revamped Distribution Sector Scheme (RDSS) identifies smart meters, consumer centricity, adoption of advanced technologies like AI/ML and capacity building of DISCOMs as major enablers for an efficient and viable power sector.

3. Deployment of advanced technologies will be critical in modernizing power utilities and equip them with tools to ensure reliable and uninterrupted power supply. Reliability improvement of power infrastructure starts with inspection, monitoring and health assessment of power system assets. While the system and processes for these activities are already in place, significance of time spent, safety of workforce and limitation of utilities in rural areas and difficult terrains where reliability and safety are primary concern assume particular importance.

4. During incidences of pandemic and natural disasters, power utilities face challenges in conducting inspections, fault detection, and providing time-bound resolution, particularly in the distribution and transmission networks. Under such circumstances, the use of advanced technologies such as drones in network monitoring, fault identification and asset health management can play a crucial role in averting prolonged system inefficiencies and maintaining the safety and reliability of the power system. Further, drones equipped with Artificial Intelligence and Machine Learning (AI/ML) technologies are opening new areas for applications to improve operations workflow and execution, reduce energy wastage, lower costs, and facilitate the use of clean energy sources in power grids.

5. I would like to congratulate USAID India and PFC team for coming out with this report regarding adoption of drone applications in the power sector. I am sure that this paper will lead to actual deployment of drones by utilities to improve their operational efficiency.

Alok

(Alok Kumar)

RIGHT TO INFORMATION

G20 भारत 2023 INDIA

स्वच्छ भारत
एक कदम स्वच्छता की ओर

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FROM THE AMERICAN PEOPLE

South Asia is one of the fastest growing regions in the world and energy is a key driver for development. Ensuring reliable electricity access is central to sustaining the region's expanding economies and supporting people's growing aspirations.

Advanced technology deployment is critical for the evolution of the power sector and drones are emerging as one such versatile solution. Drones equipped with Artificial Intelligence and Machine Learning (AI/ML) technologies are important for inspection, monitoring, data collection, and search and rescue across different sectors including agriculture, construction, and logistics. Within the Indian power sector, drone applications have the potential to support transmission and distribution utilities by enhancing operational efficiency, improving supply reliability, reducing downtime, enhancing workforce safety, and bolstering customer satisfaction.

The United States Agency for International Development (USAID) India in partnership with the Ministry of Power, under the South Asia Regional Energy Partnership (SAREP), is supporting modernization of India's power sector through introduction and implementation of advanced technologies in power utilities. Drones coupled with AI/ML and data analytics are important technologies helping to transform distribution utility operations.

This white paper, developed by USAID India in partnership with Power Finance Corporation (PFC), contributes to the understanding of drone use in Indian power utilities. The whitepaper highlights multiple global use-cases of drone applications in the power sector with a particular focus on distribution utilities.

I would like to congratulate the PFC and USAID SAREP team for their leadership in developing this resource which will be useful for Indian utilities, as well as utilities across South Asia grappling with similar power sector challenges. I believe this effort will close a crucial information gap in the journey to accelerate access to affordable, reliable, and sustainable energy in South Asia.

John Smith-Sreen

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सत्यमेव जयते

पावर फाइनेंस कारपोरेशन लिमिटेड
POWER FINANCE CORPORATION LTD.
(भारत सरकार का उपक्रम) (A Govt. of India Undertaking)

MESSAGE

Deployment of advanced technology solutions has an important role to play in enhancing the operational efficiency and improving the financial performance of distribution utilities. Taking cognizance of the same, the Ministry of Power, Government of India (GoI) has launched the Revamped Distribution Sector Scheme (RDSS), which encourages deployment of advanced technology solutions towards utility modernization.

PFC is a central nodal agency leading the implementation of RDSS across the country. As a nodal agency, the role of PFC is to facilitate deployment of advanced technology solution and modernization of power distribution. PFC is also responsible for performance evaluation of states and financing of projects related to modernization of distribution utilities under RDSS.

Advanced technology solutions such as Drone applications can drive transformation of financially burdened distribution utilities with enhanced operational performance due to limited need for human intervention, ease of operation, and precision in the results generated. PFC recognizes the need to raise awareness for the faster adoption of drone technologies to modernize operations in the power sector.

I would like to take this opportunity to appreciate the excellent work done by USAID and PFC team in developing this whitepaper. I hope this document accomplishes the end goal of promoting advanced technology solutions such as drone applications, serve as a guide to interested stakeholders and eventually, widespread adoption in India.

(Saurav Kumar Shah)

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ACRONYMS AND ABBREVIATIONS

AI/ML	Artificial Intelligence and Machine Learning
ATM	Air Traffic Management
BAU	Business-as-Usual
BOS	Balance of System
BVLOS	Beyond Visual Line of Sight
CEA	Central Electricity Authority
CG	Central Government
CTO	Chief Technology Officer
C-UAS	Counter UAS
DEM	Digital Elevation Model
DG UTMSP	DigitalSky UTM Service Provider
DGCA	Director General of Civil Aviation
DOS	Denial of Service
DS	Digital Sky
DS-ENG	DigitalSky Engine
DS-GOV	DigitalSky Government
DSM	Digital Surface Models
DSP	Drone Service Providers
DTM	Digital Terrain Models
EHT	Extra High Tension
FAA	Federal Aviation Administration
GIS	Geographic Information System
GPS	Global Positioning System
IEA	International Energy Agency
IoT	Internet of Things
IPDS	Integrated Power Development Scheme
IPP	Independent Power Producer
ITE&C	Information Technology, Electronics and Communications
LiDAR	Light Detection and Ranging
LOC	Line of Control
LT	Low Tension
MITM	Man in the Middle
MSC	Multi-Stakeholder Steering Committee
MSME	Micro Small & Medium Enterprises
NABCB	National Accreditation Board for Certification Bodies
NABL	National Accreditation Board for Testing and Calibration Laboratories
NASA	The National Aeronautics and Space Administration
NIR	Near-Infrared Radiation
NTPC	National Thermal Power Corporation Limited

PFC	Power Finance Corporation
PLI	Production Linked Incentive Scheme
QCI	Quality Council of India
RADAR	Radio Detection and Ranging
RDSS	Revamped Distribution Sector Scheme
RPAS	Remotely Piloted Aircraft System
RS	Remote Sensing
SCE	Southern California Edison
SSEN	Scottish and Southern Electricity Networks
SVAMITVA	Survey of Villages Abadi and Mapping with Improvised Technology in Village Areas
SWIR	Short-wave Infrared Radiation
T&D	Transmission and Distribution
UAOP	Unmanned Aircraft Operator Permit
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aerial Vehicles
UDAY	Ujjwal Discom Assurance Yojana
UIN	Unique Identification Number
UTM	National UAS Traffic Management
VLL	Very Low Level
VLOS	Visual Line of Sight

1 CONTEXT

Drones are emerging as versatile tools applicable across different sectors like agriculture, defense, public safety, telecom, power, insurance, transportation, logistics, entertainment, mining, and construction. Limited human intervention, ease of operation, and precision in the results generated make drones suitable for widespread civilian applications. A broad spectrum of commercial drone applications exists today, including inspection, monitoring, data collection, search, and rescue.

In India, one of the first notifications on the subject was a public notice issued in 2014 by the Directorate General of Civil Aviation (DGCA). In October 2017, the aviation regulator released draft norms for the usage of drones, followed by the release of another notification by the Ministry of Civil Aviation (MoCA), Government of India (GoI), 'Drone Rules – 2021' on August 25, 2021 (Ministry of Civil Aviation - PIB, 2021), which paved the way for their liberated operation in the country. Built on the premise of trust, self-certification, and non-intrusive monitoring, the objective of the new rules was to improve the ease of doing business while balancing safety and security considerations (Ministry of Civil Aviation, 2021). These rules thus enable faster development of the drone ecosystem and open up the scope for new applications and use cases.

The Government of India (GoI) recently flagged off 100 Kisan Drones in different towns and cities to spray pesticides on farms across India. The Kisan Drones will be used to boost the agriculture sector for crop assessment, digitization of land records, and spraying insecticides and nutrients. The SVAMITVA scheme is another example of the optimistic view of growing drone applications that use Unmanned Aerial Vehicles (UAVs) to map land parcels and provide a 'Record of Rights' to village household owners for issuance of legal ownership cards.

Drones are significant job creators and enablers of economic growth for India, due to their reach, versatility, and ease of use, especially in remote areas and terrains. On the back of a strong information technology sector and domestic demand, India sees the potential to be a global drone hub by 2030. The drone services industry is forecast to grow to INR 300 billion over the next three years, creating 500,000 jobs, according to government data (Ministry of Civil Aviation - PIB Delhi, 2021).

Drones equipped with Artificial Intelligence and Machine Learning (AI/ML) technologies[1] are opening new areas for applications. AI/ML-based technology deployment is now catching up as a critical component for the electricity sector, where it has the potential to improve workflow and execution, reduce energy wastage, lower costs, and facilitate the use of clean energy sources in power grids. These solutions are found to have greater relevance in areas such as, but not limited to, construction-site monitoring, fault detection, asset management, predictive maintenance, and predictive theft detection.

[1] ***Artificial intelligence (AI)*** is the ability of a computer program or machine to simulate human intelligence by analyzing its environment and taking actions with some degree of autonomy.
Machine learning (ML), a subset of AI, is a method of data analysis that enables machines to learn from data, identify patterns and draw conclusions, without being programmed to do so.

Drone applications, combined with AI/ML, are gaining acceptance in the power sector globally, and utility providers and developers in India are exploring the use of drone-based applications. Although they are in the initial stages, they are poised to modernize how energy distribution and consumption happens. Some of the early adopters of drone applications in India include transmission utilities and renewable energy project developers.

The Indian power distribution sector, which remains a weak link in the electricity supply chain, is an ideal candidate for drone technology deployment and to raise the efficiency of operations. Inadequate capacity, aging infrastructure, obsolete asset management practices, high technical losses, power theft, and low investment in modernization are some of the main issues affecting the operational and financial health of the country's already debt and loss-laden power distribution companies (Discoms).

Since drones are still in the early stages of adoption in the Indian power sector, some utilities are implementing small-scale Proof of Concepts (POCs). A large number are yet to explore the opportunities they present. The drone ecosystem is continuously evolving, with more and more start-ups established in recent years.

Power Finance Corporation Limited (PFC), the nodal state agency responsible for financing and facilitating reforms in the Indian power sector, recognizes the need to raise awareness for the faster adoption of drone technologies to modernize operations in the power sector. PFC has requested the South Asia Regional Energy Partnership (SAREP), the flagship regional energy program of the United States Agency for International Development (USAID), to prepare a whitepaper on the applications of drone technologies for the sector.

To facilitate the same, SAREP has prepared this whitepaper, "Drone Applications for Power Sector", which covers the following:

- Drone applications and use cases for the power sector,
- Cost-benefit analysis of drone applications,
- Drone-market landscape,
- Benefits and challenges of drone applications,
- Key regulatory and policy provisions to promote drone applications, and
- Way forward for faster adoption of drone applications in the power sector

Drone Applications for Power Sector

2 DRONE APPLICATIONS FOR POWER SECTOR

Over the last decade, India has become the world's third-largest producer and consumer of electricity and is the fourth-largest installer of renewable energy capacity globally. India has announced plans to become a USD 10 trillion economy by 2030 (Dhasmana, 2019). The supply of affordable and reliable power is a prerequisite for any country's development goals.

India is also one of the most vulnerable countries to climate change (Eckstein, et al., 2021). Extreme weather events occurring frequently, pose myriad risks to the energy infrastructure and can result in recurring power cuts that require frequent maintenance and higher capital investment to build a resilient grid. The COVID-19 pandemic seems to have mirrored a climate disaster and displayed the far-reaching impact it could have on electricity demand patterns, power system design, changes in load profile, and fail-proof O&M practices.

To be prepared for climate challenges and meet the largest spike in energy demand in the world over the next two decades (International Energy Agency, 2021), India needs to modernize and strengthen its utilities. The Government has been making consistent efforts through various schemes and policy reforms to improve the financial and operational health of Discoms.

In the past, steps to encourage automation and use of Information Technology (IT) in the power distribution sector, such as the Ujjwal Discom Assurance Yojana (UDAY), and Integrated Power Development Scheme (IPDS), have been undertaken through a series of schemes. These have enabled digitization by establishing data centers, GIS mapping of consumers, asset mapping, online energy auditing, accounting, and the use of devices like sensors and smart meters.

India's Discoms have remained ill-equipped to recover the cost of sale for electricity and have been accumulating huge losses on account of gaps in revenue realization. Most recently, India launched the INR 3-Trillion Revamped Distribution Sector Scheme (RDSS) (Ministry of Power, 2021), which proposes an outcome-driven and result-oriented framework to help improve the performance of Discoms in a time-bound manner. The RDSS recommends digitization and the use of AI/ML-based solutions, among others as an enabling means to resolve the operational and financial shortcomings of India's Discoms.

Drones combined with AI/ML-assisted data analytics, present a significant and cost-effective intervention to improve operational efficiencies. At the minimum, they can help identify, predict, and isolate faults, thereby allowing utilities to streamline operations and maintenance (O&M). Drone applications are manifold, ranging from project execution, and monitoring to network vigilance and equipment/line inspections thereby reducing system interruptions and increasing the asset health. They also have a significant role in protecting the health and safety of manpower that are presently deployed to carry out a physical inspection of network infrastructure and components. The applications find themselves of great use in the difficult-to-access areas and adverse terrains.

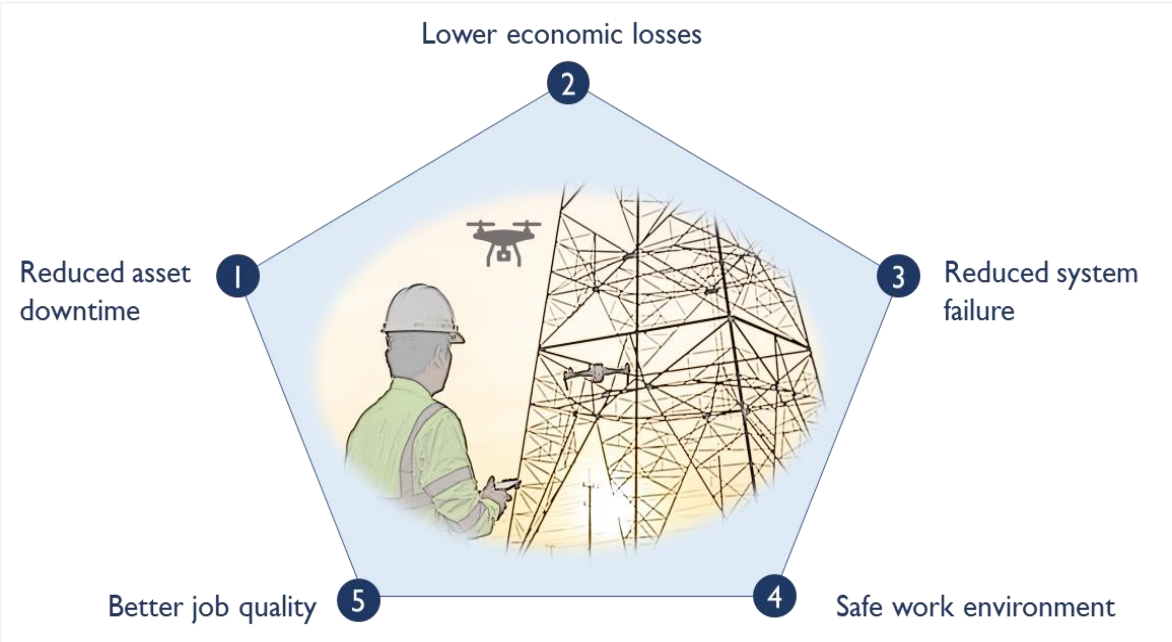
2.1 Benefits of Drone Applications

Drone technology could be a game-changer for India's power sector. Drones are used to conduct surveys, and inspections, making routine maintenance of power system infrastructure safer and faster while reducing costs and delivering greater value. With nominal fuel requirements, drones are environment-friendly and provide high-resolution images, which can be analyzed with AI-enabled solutions. They are relatively inexpensive to produce and can fly for several hours. Drone applications backed with AI/ML technologies can support utilities in undertaking predictive maintenance, initiating prognostic analysis, and pre-empting outages.

Key benefits for the power sector by drone applications are:

- Reduction in downtime - by early fault detection and predictive maintenance planning
- Reduction in economic losses - directly for the utility and indirectly for the consumer and the region served by the utility
- Enhanced reliability - potential risks and defects are identified and revealed by drone inspections, enabling preventive actions, and reducing the possibility of system failure
- Safe working environment - the adoption of drones replaces manual inspections and thus reduces occupational hazards
- Job quality - drone applications transform the 'labor-intensive jobs' into 'technical jobs'

Figure 1: Benefits of drone applications



2.2 Drone Applications for Power Sector

Broadly speaking, drone applications for the power sector are categorized into: i) Applications for distribution and ii) transmission; iii) applications for clean energy projects including, solar and wind projects; and iv) other applications

Table 1: Drone applications for the power sector

Distribution	Transmission	Clean Energy Projects	Conventional Generation
▪ Visual and thermal inspection of distribution assets ▪ GIS mapping ▪ Theft detection ▪ Distribution asset management and predictive maintenance using AI/ML ▪ Vegetation management ▪ Distribution infrastructure installation and maintenance	▪ Routine Transmission infrastructure inspection ▪ Condition monitoring, predictive maintenance and prognostic analysis using AI/ML ▪ Corona detection ▪ Line corridor inspection ▪ Emergency management for grid resilience	▪ Applications for solar power projects ▪ Applications for wind power projects	▪ Applications for conventional generation- thermal, hydro, nuclear ▪ Construction and progress monitoring • Applications for emissions monitoring

Power sector utilities in many countries such as Australia, Canada, China, Spain, the U.S., and the U.K, have already started to tap the potential of drone technologies to improve their operational efficiency (Yue, 2021). For instance, utilities in the U.S., such as Southern California Edison (SCE), have started to utilize drone technologies in a big way. Drones inspect about 27% of its 50,000-square-mile service area (Netter, 2021) and cover more than 400,000 poles, transformers, and lines in SCE's high fire-risk areas. Similarly, the National Grid of the U.K. has developed an in-house team of drone operators to inspect its overhead lines and substations (Gridline - The magazine for landowners, 2017).

Some of the early adopters of the drone technologies in the Indian power sector include transmission utilities such as PowerGrid Corporation of India Limited (PowerGrid), Delhi Transco Limited (DTL); renewable utilities such as Renew Power, Mahindra Susten, and private Discoms such as Tata Power-DDL and BSES Rajdhani Power Limited. Many of the early projects are however limited in scope and many of them are in the pilot stage.

The next section of the whitepaper focuses on uses cases and applications of drone in Distribution, Transmission, and clean energy projects. The section provides case studies of actual drone implementations and learnings received. Additionally, assessment of benefits and costs of investments in comparison to a reasonable traditional or "business-as-usual" case is made allowing utilities to understand and make informed decisions.

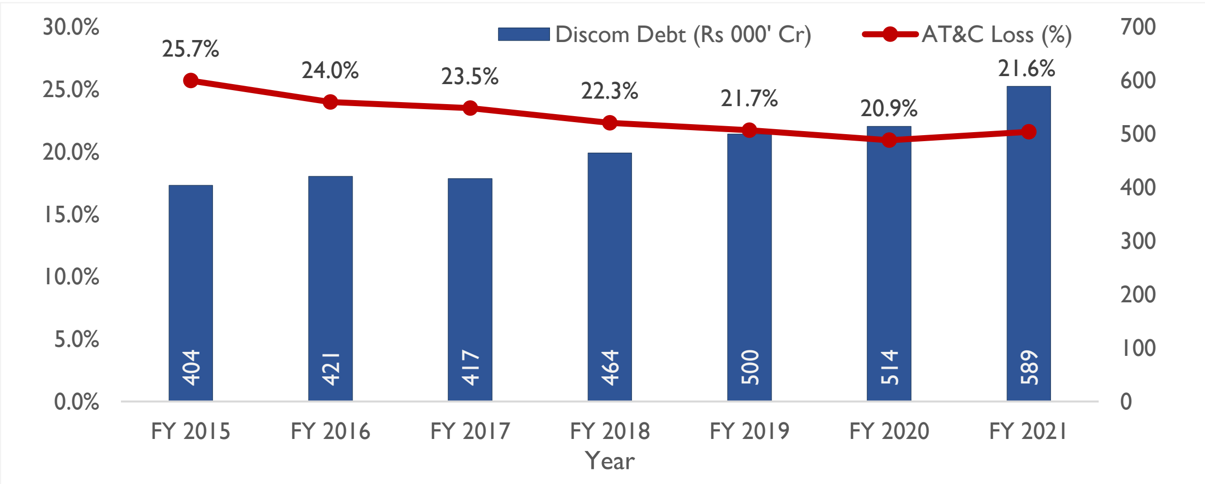
Drone Applications in Distribution

3 DRONE APPLICATIONS IN DISTRIBUTION

Distribution is the Achilles' heel of the entire power sector value chain. Inadequate service quality with frequent outages, high system losses, tariffs that do not recover costs, low levels of billing and collections, aging workforce with limited upskilling opportunities are some of the issues faced by the Indian distribution utilities. As revenues ultimately originate from consumers at distribution end and provide cash flow for the whole value chain, distribution acts as a cash register. Hence the profitability and performance of distribution companies is closely tied to operational wellbeing of whole power sector.

Power distribution sector remains a concern with the AT&C losses hovering around 21% in the past few years. Owing to the rising O&M and interest costs, AT&C losses have increased to 21.6% in FY 2021 as compared to 20.9% in FY 2020 (Figure 2). The number has yet to reduce to targeted 12%-15% range, as envisaged by the Revamped Distribution Sector Scheme (RDSS) launched by MoP (Ministry of Power, 2021). Furthermore, most Discoms are incurring vast losses and increasing debts every year.

Figure 2: Performance of Distribution Utilities



Source: Tenth Annual Integrated Rating and Ranking of Power Distribution Utilities (Ministry of Power, 2022), *Report on Performance of Power Utilities* (PFC, 2020)

Geographically, large states of India such as of Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Telangana and Uttar Pradesh, account for more than 90% of all India Discom losses (PFC, 2020) and have AT&C losses more that the national average (20%). O&M expenditure for distribution utilities alone in the country is around 19% of the overall total expenditure. During FY 2019, total O&M costs for 55 distribution utilities were recorded at INR 1.63 trillion (PFC, n.d.).

On the other hand, the performance of the distribution utilities owned by private corporates remains healthy over the years. AT&C losses stand under 10% for private Discoms such as BSES Rajdhani Pvt Ltd (BRPL), BSES Yamuna Power Ltd. (BYPL), Tata Power Delhi Distribution Ltd (TPDDL) and Torrent Power in Delhi and Gujarat supported by adoption of advanced technologies and superior O&M efficiencies.

As the power infrastructure expands and demand increases, the need for efficient O&M also grows. O&M, however, remains heavily dependent on manpower, making it both expensive and hazardous. Manual inspections also entail low efficiency and limitations in reaching difficult locations.

Unlike conventional generation assets, distribution assets especially encounter these issues as they may often spread across large areas and hard-to-access terrain or highly congested areas. The O&M of distribution assets has opened a huge market for the application of drones, which can provide cost-effective, safe, and accurate assessment for routine predictive and preventive maintenance of such infrastructure. Use-cases for some of significant applications are as elaborated below:

Table 2: Use cases for drone applications in distribution network

Application Area		Role Of Drone Applications	Use Cases
1	Visual and Thermal Inspection of Distribution Assets	Reduced inspection time, O&M cost saving and improved accuracy in fault detection	• BSES Yamuna Power Limited (BYPL), Delhi • BSES Rajdhani Power Limited (BRPL)
2	GIS Mapping	Mapping in difficult terrain for topographic/route, surveying, identification of illegal connections, and accurate consumer mapping.	• Tata Power Western Odisha Distribution Ltd (TPWODL), Odisha
3	Theft Detection	Reduced AT&C losses by identification of illegal connections.	• Tata Power Western Odisha Distribution Ltd (TPWODL), Odisha
4	Distribution Asset Management and Predictive Maintenance	Early detection and failure of assets.	• BRPL, Delhi • BYPL, Delhi • TPDDL, Delhi
5	Vegetation Management	Highly accurate 3D models of tree heights and vegetation growth in clearance zone.	• Pound Farm, Suffolk, UK
6	Distribution Infrastructure Installation and Maintenance	installation of Internet of Things (IoT) sensors on the live electrical network	• The Grid Company Linja, DSO in Western Norway

The following sub-sections provide a detailed overview of the drone applications and use cases in distribution O&M.

3.1 Visual and Thermal Inspection of Distribution Assets

The use of drones can improve visual and thermal inspections of distribution infrastructure such as distribution poles, towers, insulators, substations, and distribution transformers at a lower cost while minimizing the risks. As an alternative to manual inspections, drones are safer, quieter, efficient, less time-consuming and more environment friendly.

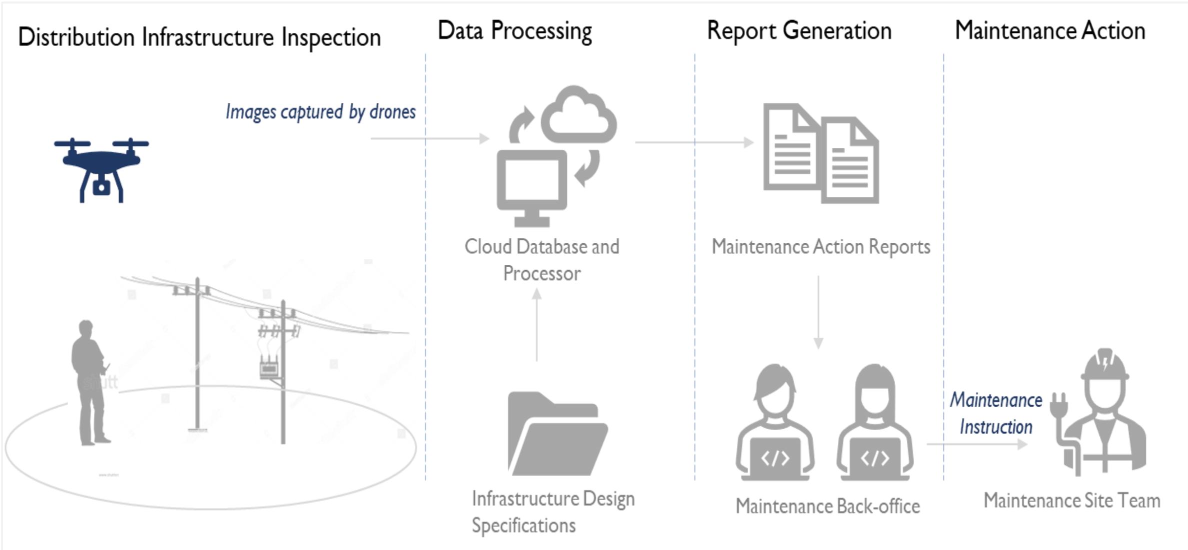
For distribution infrastructure inspections, drones are generally equipped with high-resolution still, video, and infrared cameras. Drones can be manually operated through remote controls or from the ground control stations. Pre-programmed waypoints can be defined for the drones to perform routine and regular inspections and provide detail-oriented, high-quality images from optimal angles.

The drones' images are stored in a central database, generally a cloud-based system. The database also stores the standard design specifications of the distribution infrastructure elements such as poles, insulators, conductors, transformers, etc.

The AI/ML-based system processes images, compares them with standard design specifications, and runs diagnostic analyses on various elements for corrosion detection in metal structures, identification of faults/hot spots/weak links in conductors, insulators, transformers, line accessories, wear and tear in poles components, and missing members/parts, if any, vegetation growth, etc.

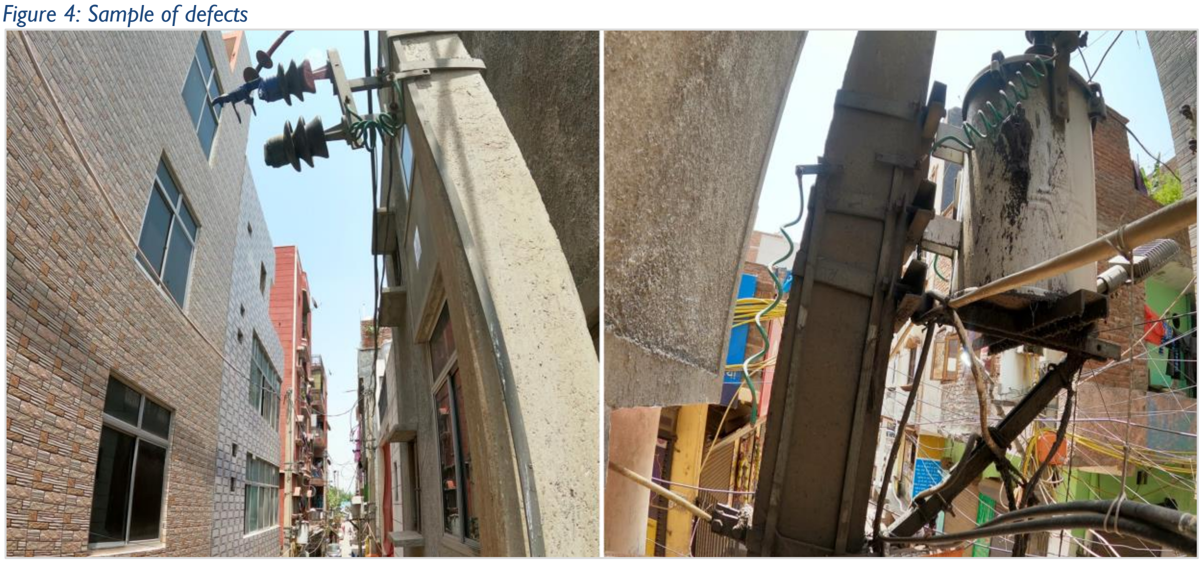
Finally, the AI/ML system generates reports for the maintenance action required and optimal resource utilization plan based on the severity. Videography of the distribution line and the surroundings also provides terrain congestion knowledge and enables easier planning of maintenance and post-fault repair activities.

Figure 3: Distribution Infrastructure Routine Inspection Using Drones



The following figures presents a sample of common defects observed during drone inspections that are difficult to notice during manual inspection without employing deploying maintenance staff and hydraulic equipment such as bucket trucks to inspect distribution infrastructure. Drone applications obviate the need for de-energization of the live line that is sometimes required to permit physical inspections.

Figure 4: Sample of defects



Note: 1- missing fuse; 2- earth wire fault
Source: Vidrona Ltd

Figure 5: Missing fuse and earthing failure in DT

Source: Vidrona Ltd

Figure 6: Sample defects

Note: 1- loose nut and bolts; 2- line sagging; 3- earth wire missing in tower
Source: Vidrona Ltd

Figure 7: Sample of defects

Note: 1- broken insulator; 2- flash mark on insulator; 3- hotspots in overhead lines; 4- slippage of conductor
Source: GarudaUAV

Case Study- India

BSES power distribution companies partnered with Noida-based Garuda UAV in 2020 to map and monitor distribution assets. Combined with end-to-end solutions for maintenance and planning, drones carry high-definition cameras for visual inspection and infrared ones for thermal imaging that help identify hotspots.

The dual cameras allow the inspection of overhead lines and equipment, grid sub-stations, connections, damaged switches, capacitors, detection of theft of equipment and profiling intelligent lines. Both BYPL and BRPL have undertaken projects for visual and thermal mapping of the distribution infrastructure using UAV. The utility finds the successful adoption of drone technology a huge step in preventive maintenance exercise critical for ensuring reliable power supply and theft identification.

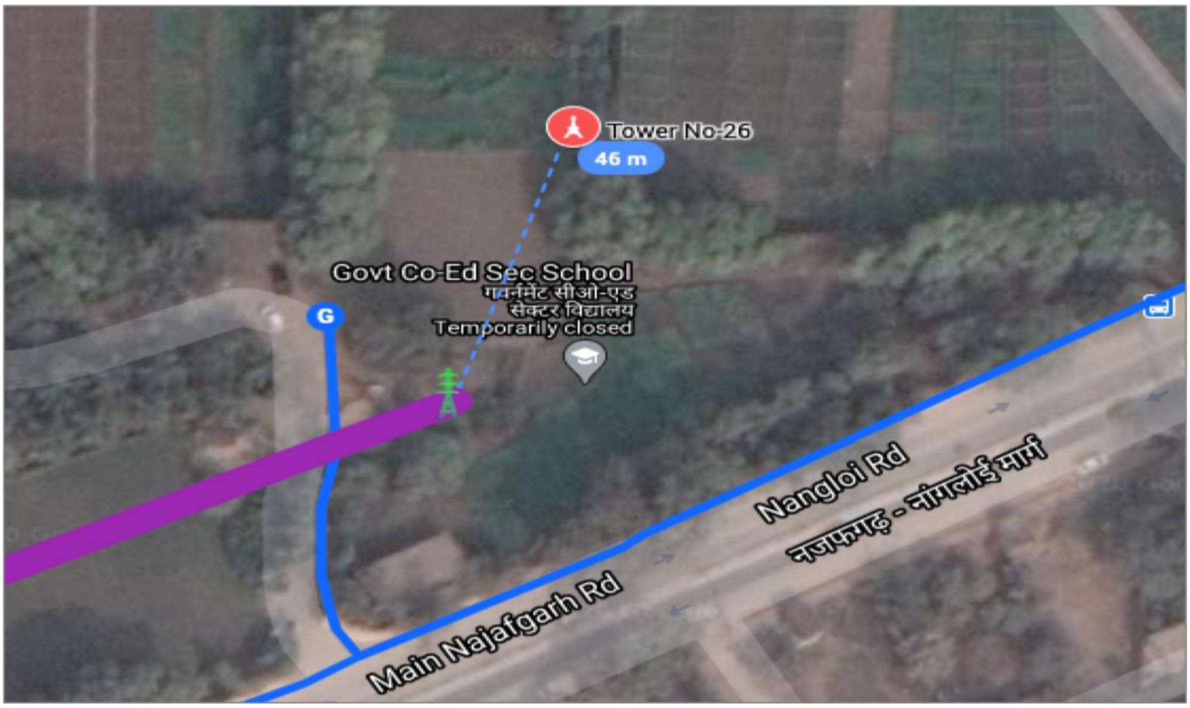
Besides this, BRPL has also conducted a pilot in 66 kV Paschim Vihar Grid Station, 66kV Bodella I – Paschim Vihar Circuit I and 2 and 33 kV Mukherjee Park Circuit 3 near Chaukhandi in New Delhi. With successful pilot testing, BSES has decided to go ahead with its the plans to use drones for O&M activities.

Sources:
1. *Discussions with BSES Delhi*
2. *(India Today, 2020)*

3.2 GIS Mapping

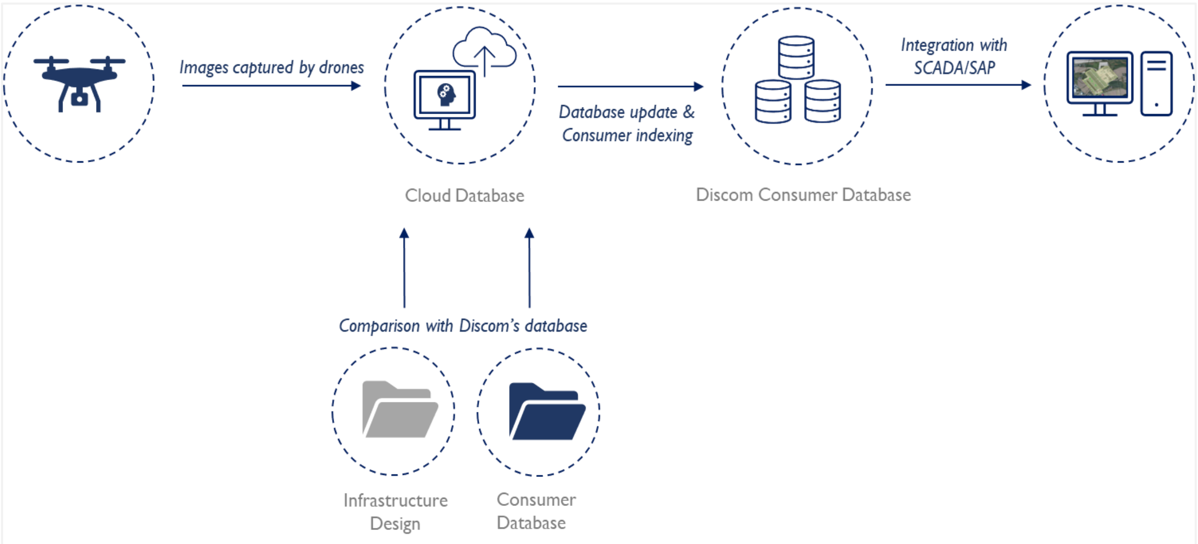
Maintaining an accurate, up-to-date, and comprehensive database of assets, both above and below ground, has been a challenge for utilities. Drone applications can be combined with GIS or Global navigation satellite system (GNSS) and Remote Sensing (RS) technologies to map distribution assets and prepare detailed 3D models and inventory of the plant, equipment, and installations.

Figure 8: Tower mapping



Note: green - accurate position of tower detected by drone application, red - incorrect position
Source: Vidrona Ltd

Figure 9: GIS mapping and consumer indexing

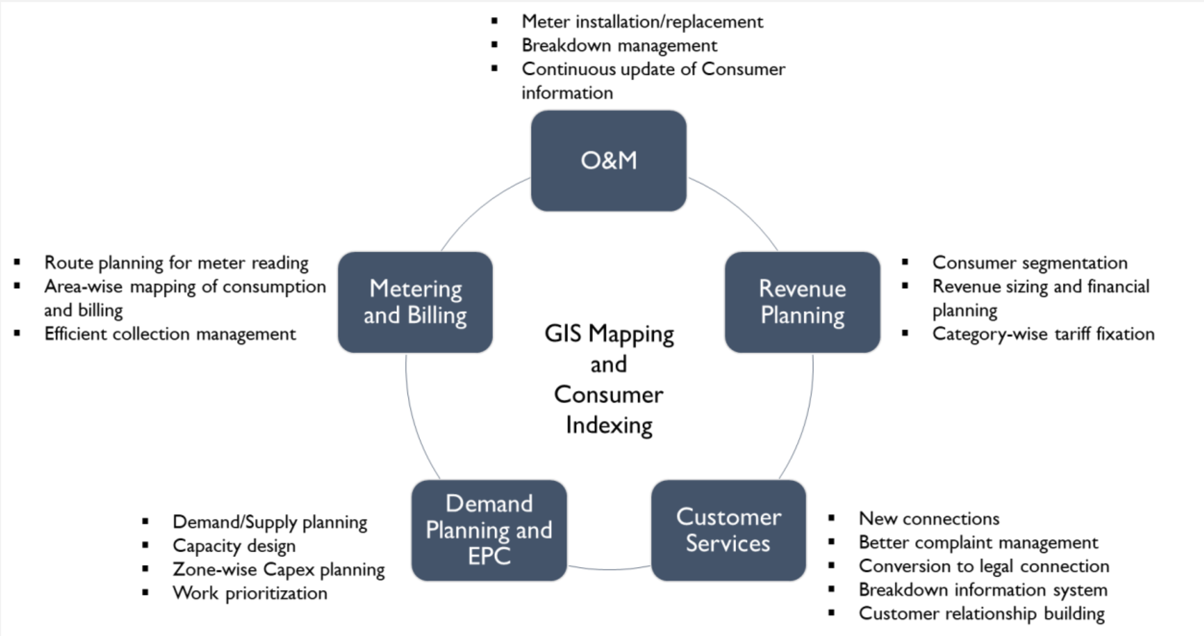


Furthermore, linking the consumer and asset data to a geographic location on a map, provides Discoms a powerful decision-making tool, enabling them to track and update the unauthorized connections. Using drones, substation and LT connections can be cross-referenced with the Discoms database and updated in a much shorter time.

The consumers mapped using GIS and identified based on their unique electrical address can be segregated: i) substation-wise; ii) Feeder-wise; iii) DT-wise. This aids in calculating AT&C losses at DT and feeder level and identifying areas with high losses.

Also, the integration of GIS with other available software such as Supervisory Control and Data Acquisition (SCADA), Enterprise resource planning (ERP), and Systems, Applications & Products (SAP) can provide real-time data on a geographical view of the electrical network, thus enhances the operational efficiency via real-time monitoring.

Figure 10: Benefits of GIS mapping and consumer indexing



Drone application combined with GIS mapping can also assist in new construction or existing capacity expansion, starting with a feasibility study, planning, tendering, and progressing to detailed surveys, habitation analysis, project delivery, and completion. Drones can be employed in rural, mountainous areas with rugged terrain for topographic/route mapping and surveying, progress monitoring, and maintenance.

Case Study- India

The Delhi arm of Tata Power's distribution entity has done pilots on completing GIS mapping, which assists in operation and maintenance activities, and inspection of powerlines. Since GIS mapping of assets were already in advanced stages, therefore, drones were used to complete the tasks.
Tata Power has started using drones to conduct GIS mapping of assets in the recently acquired Discom in Odisha using. From an earlier circuit length of 2 km/day covered via manual inspection, drones covered 6 km/day on average. Drones have reduced the inspection and mapping time to 3 days from 10 days. The company is deliberating on all the use-cases across departments and geographies to develop a central team for being more efficient in using drones.

Key results

- Circuit length of 6 km/day covered as compared to 2 km/day in BAU scenario
- Inspection and mapping time reduced to one-third compared to BAU scenario

Sources:

1. *Discussions with Tata Power- Delhi Distribution Limited.*
2. *(Sur, 2022)*

3.3 Theft Detection

Power theft continues to be a menace, despite being a legal offence. It accounts for a significant share of Indian Discoms' non-technical losses, resulting in significant revenue erosion. Power thefts are a safety hazard as tampering can create unsafe and potentially fatal conditions that could result in electric shocks, fire, or explosion. It adversely affects the functioning of the distribution grid and hampers supply quality. Drone surveillance can capture high-resolution aerial pictures, effectively recovering evidence, swiftly prosecuting power thieves, and dismantling clandestine and unauthorized connections.

Figure 11: Theft cases identified using drone

Source: Vidrona Ltd

Case Study- India

In the Odisha Discom, Tata Power took up detection of power theft in remote locations. With drone officials were able to capture and take those images without anyone in the public noticing. Earlier they used to conduct raids in late evening, night or early morning as the lines were amid communities.

During the pilot, Tata Power was also able to detect power theft in rural areas involving connections taken for tube wells or irrigation. With many states subsidising power connections for farming, Kiran Gupta (CEO and executive director at Powerlink Transmission) said that connections taken for tube wells were being extended to nearby houses. Using drones, they have really been able to understand how the electricity connection from one cable is being tapped and being taken to another place.

As for remote meter reading in rural areas, Tata Power was able to **save around 37.8 percent** in cost with the help of drones. "Earlier, we were giving around Rs 8 per meter reading. However, with drones we incurred an expense of only Rs 5," Gupta said. Even though Tata Power has Bluetooth-enabled meter readers in a few areas, due to limitations in distance and network, they were not able to manually read meters. With drones, they were able to.

<u>Key results</u>

- theft cases were detected which were difficult to locate with manual inspection
- *Meter reading cost reduced by Rs 3 per meter*

Sources:

1. *Discussion with Tata Power West Odisha Distribution Ltd*
2. *(Sur, 2022)*

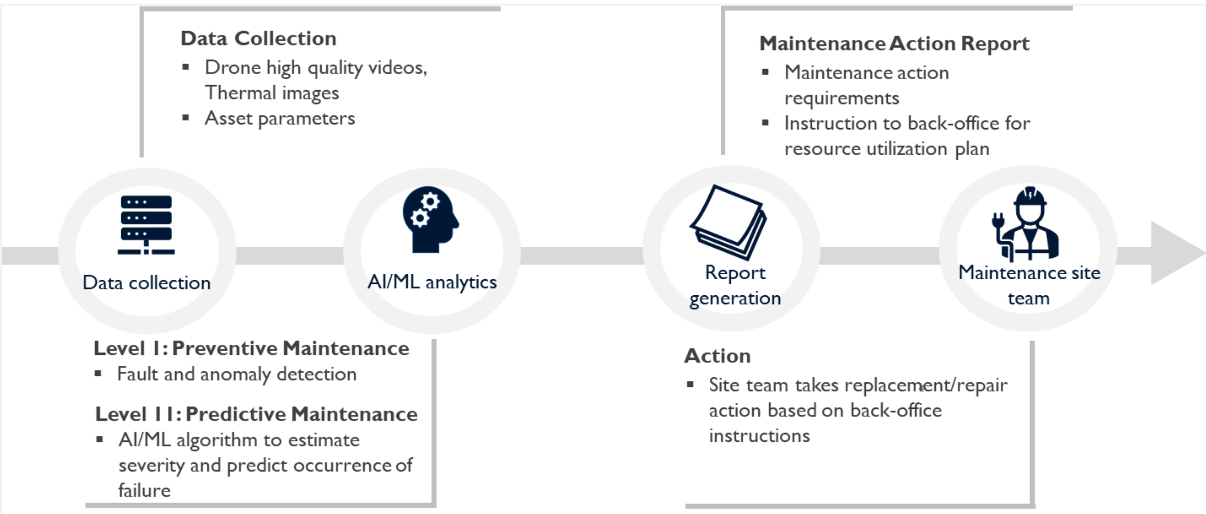
3.4 Distribution Asset Management and Predictive Maintenance Using AI/ML

The standard way to keep assets operational for a long time has been routine maintenance which comes under the preventive maintenance[2]. However, with predictive maintenance gaining popularity, maintenance is being performed based on estimated degradation of parts, rather than on a set interval of time. In areas that are remote or difficult to access, drones can be used to assist in predictive maintenance.

Combined with AI-based image processing technology, camera-equipped drones can assist in corrosion detection, faults such as damaged conductors, potential insulator damages, and distribution transformer hotspots. Drones can monitor the temperature and current of distribution transformer using thermographic camera and current measuring device. When such information is gathered over a period, data can be further processed by AI/ML tools to establish historical patterns for network assets. With the captured data, in case of any abnormalities, an alarm can prompt local operation station to act. Subsequently based on the trend progression, a prognostic analysis for arresting and reversing the abnormal occurrences can be undertaken.

Based on the evidence-driven and location-specific intelligence collated, corrective actions to improve planning and design at the network, asset, and component level can be laid out with a reasonable degree of confidence.

Figure 12: Distribution asset management and predictive maintenance using AI/ML



[2] Current equipment maintenance strategies fall into three main categories. The first is 'run-to-failure'. In this category, interventions occur only after a transformer has already failed.
The second category is preventive maintenance. Here, maintenance actions are carried out according to a planned schedule.
The final category, predictive maintenance, is the most cost effective. Predictive maintenance attempts to assess the health conditions of each device.

Case Study- India

'v-Sense' is a solution developed by VIDRONA limited for asset management. It uses AI based predictive and prescriptive analysis to capture and monitor health of network assets (HV/ LV lines, grid sub-stations, OH network equipment, switchgears etc.). Key features of the solution include:

- It helps to inspect various components comprising the network.
- It uses drone-based high-resolution imagery and infrared thermo-scanning. The images are transferred to AI software through cloud server. AI has an existing database of over 100 faults (viz. salt deposition, rusting, ground bound error, conductor faults). The imagery is compared, and faults are identified well in advance. This solution has been implemented in BSES Delhi, Tata Power Delhi Distribution Limited (TPDDL) and Adani Power Limited.
- Supports in reducing cost of failures by early detection and increasing the asset life and helps in informative decision making.

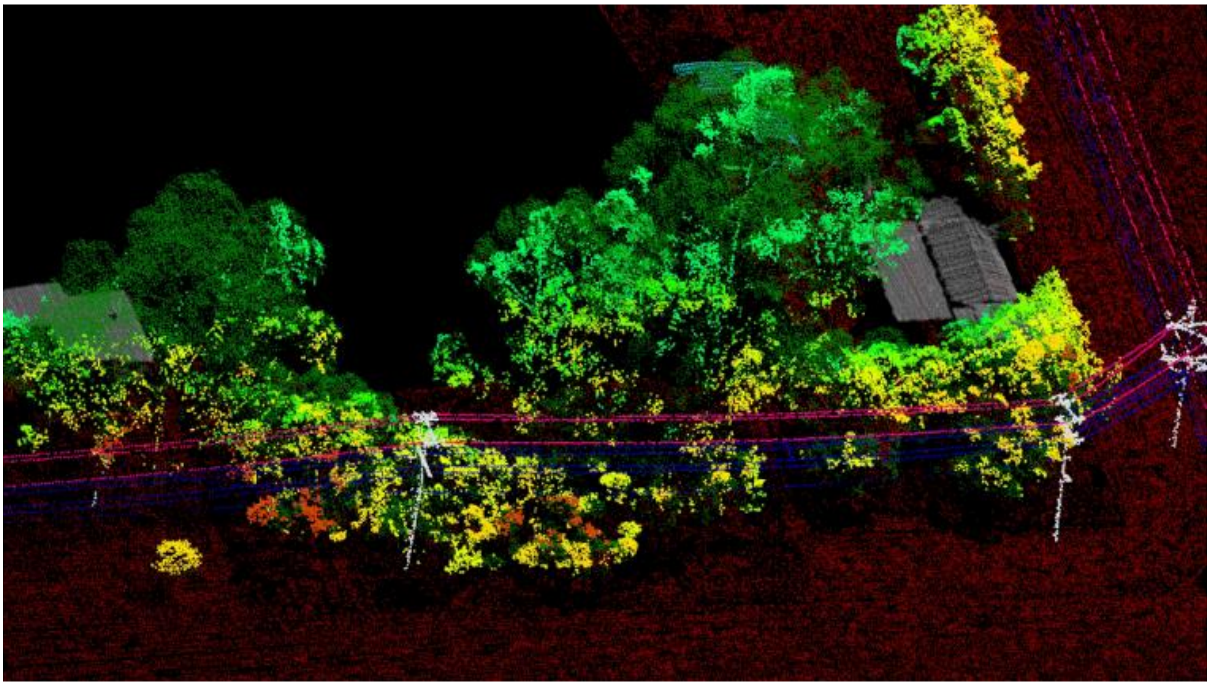
Sources:

1. *Discussions with TPDDL*
2. *(Vidrona, n.d.)*

3.5 Vegetation Management

Utilities typically track vegetation growth near their overhead lines using GIS. Drones equipped with LiDAR sensors can complement the GIS to develop highly accurate 3D models of tree heights and locations over the entire line corridor. These models combined with AI/ML technology can help identify vegetation growing inside the minimum clearance zone of the power lines, paving the way for planning the trimming operations to keep the lines free of any interference.

Figure 13: 3D model of a distribution line constructed by LiDAR technology



Source: (Torró, 2018)

Case Study- United Kingdom

Pound Farm in Suffolk, UK, sought to identify trees in poor health and overgrown vegetation that could damage the power lines that could damage the lines in the event of forest fires or cause outages otherwise.

Collaborating with Routescene, 2Excel Geo, Fera Science and Dielmo 3D, a 49-hectare site consisting of ash, oak, maple, and birch amongst other tree species, with a mix of young and ancient woodland, complete with wildflower meadows was surveyed.

Four different imaging techniques: LiDAR, RGB (Visible Imaging Sensor), Multispectral (collects wavelengths that fall outside the visible spectrum such as near-infrared radiation - NIR, short-wave infrared radiation – SWIR and others) and Hyperspectral (measure in narrower and more numerous bands than multispectral sensors), were deployed and the ability of each to identify signs of Ash dieback was appraised.

The area has been affected in recent years by the phenomenon of Ash dieback, wherein a fungus infection quickly kills the ash trees. There are 33kV powerlines cutting through the middle of the forest.

Using the four technologies, vegetation was profiled to assess tree-health and evidence of disease and risks to power lines from overgrown vegetation. This survey was found beneficial in assessing tree health and the ensuing information was used to easily manage vegetation.

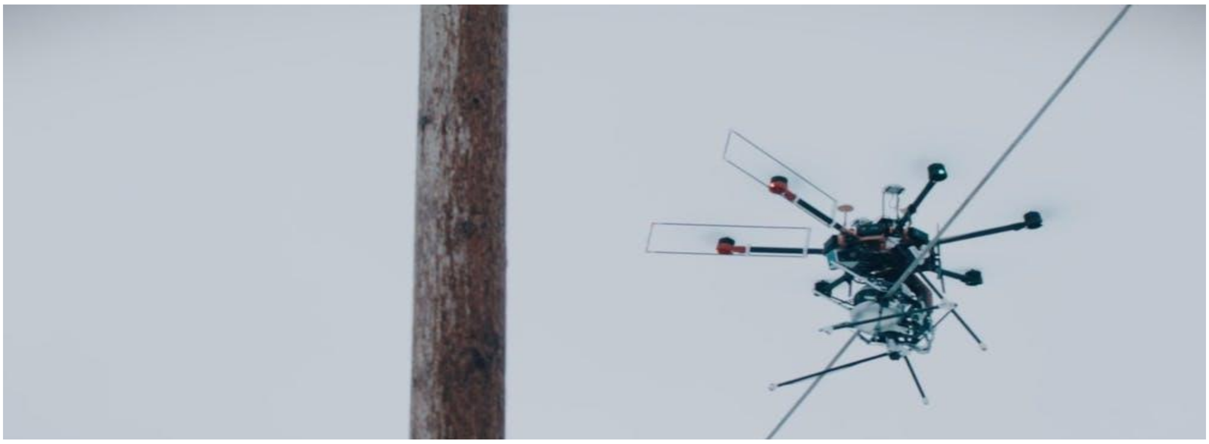
Source: (Engel, 2021)

3.6 Drone Applications for Distribution Infrastructure Installation and Maintenance

In a first-of-its-kind application, drone payloads have included IoT sensors to be installed on the live electrical network at selected points by automated operations, thereby obviating both physical deployment and line outage.

The Grid Company Linja, a DSO in Western Norway, together with Heimdall Power, an IoT Service Provider, undertook a pilot project to install IoT sensors on a live power line at Bryggja, Norway, using an autonomous drone installation technique. Autonomous drones can fly and move around independently and are capable of self-positioning on a target location. Heimdall Power used these autonomous drones for placing and installing a ball-like IoT Sensor (Heimdall Neuron) on a power line without any disruption to the grid.

Figure 14: Installation IoT sensor on power line by autonomous drone



Source: (T&D World, 2022)

Figure 15: IoT sensor installed on the powerline

Source: (Grov, 2022)

Case Study- Norway

Heimdall Power has successfully installed their IoT multi-sensor on a powered line using their patented autonomous drone installation method. This is the first time that an IoT sensor is mounted by a drone on a powered line. The drone installation enables setting-up of the multi-sensor, the Heimdall Neuron, on powered lines up to 450 kV without any disruption to the grid.

"*With this, we remove the need for use of helicopters in difficult to access areas and thereby save cost for the grid companies. This achievement falls well in line with our product offering that focus on solving key environmental challenges by leveraging state-of-the-art technology*", explained Øyvind Teigen, CTO in Heimdall Power.

Such installation of IoT sensors on a power line helps in creating "Digital Twins" of the power line and subsequent optimization and real time monitoring of the electrical network.

Key results

Observations from IoT sensor help in –

- describing and predicting asset behavior
- validating forecasts by planners
- supporting network automation, including instant recognition of faults and their isolation
- enabling digital mapping of performance parameters in real time using AI / ML and data analytics and developing dashboard
- providing operational intelligence and situational awareness for effective network management, including network capacity optimization
- Power Quality monitoring and security and operations surveillance

Source: (T&D World, 2022)

After a natural disaster such as storms, floods, and heavy rains, when terrain conditions may be unknown and fast response times are critical, drones can provide invaluable insights and support. They can quickly access areas that may be inaccessible due to water or fallen trees. Furthermore, drones can collect information that can help utilities send the right equipment and personnel to the correct location to restore power as efficiently as possible.

Additional use cases of drone in distribution include

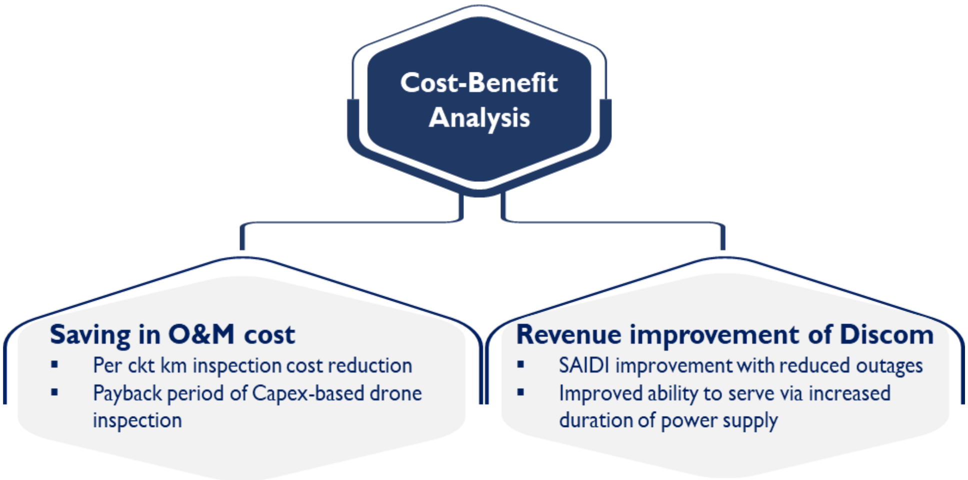
1. Civil works related to building tracking and health monitoring – assess the health of buildings, substations, and remedial suggestions
2. Street light management – asset tracking and maintenance, identify metered and non-metered lights and estimate the cost of effective maintenance
3. Safety-related violations in areas where in HVDS is implemented

3.7 Cost-Benefit Analysis

In the previous section, multiple use-cases for drone applications demonstrate the benefits, such as faster and reliable service, reduced downtime, safer work environment, and improved job quality. These benefits will result in overall economic gains for the utilities. In this section, a cost-benefit analysis is carried out by comparing expenses involved in drone operations vis-à-vis Business-As-Usual (BAU) scenario. The benefits can be broadly classified as two major areas:

A. Savings in O&M cost
B. Revenue improvement of Discom

Figure 16: Proposed benefits of drone applications for Discom



Savings in O&M cost

The following methodology was adopted for the cost-benefit analysis.

- Scenario development
- Data collection
- Estimation of costs
- Analysis of cost-estimates

Scenario Development- Distribution

In the Indian context, the adoption of drone technologies is at a very nascent stage. There are use-cases available for application of drone in the inspection of distribution assets, GIS mapping and theft detection An inspection of 33 kV distribution line in an urban area is considered for the analysis. For the comparison of BAU vis-à-vis drone applications, following attributes are taken into consideration (Table 3).

Table 3: Assumptions for the cost-benefit analysis for distribution line

Assumption Head	BAU Scenario	Drone Application
Team	1 Engineer, 2 linemen, 1 helper	1 Engineer, 1 drone pilot
Routine inspection/day	1.75 circuit km	3 circuit km
Inspection Data	Manual data collection and reporting	Automated data collection and processing of reports by cloud-based applications
Transport to site and allowances	Same cost/day for both scenarios	
Finance cost	The costing is activity-based and includes the interest and financial cost for both the scenarios	

Data Collection

The SAREP team held meetings with multiple drone service providers that are active in the Indian power sector, to validate the assumptions and assess the costs involved in both the BAU scenario vis a vis usage of drones.

Cost Estimation

A cost estimation was done for BAU scenario and was compared against two scenarios wherein drones were deployed:

- Case 1 – Rental or OPEX model i.e., when the drone-as-a- service (DAAS) are procured from a third-party
- Case 2 – In-house or CapEx model i.e., when the distribution licensee/utility itself procures and operates the drones

Case 1 - Rental or Opex Model

Details of rental, salaries, and other monthly expenses are available and are considered for both scenarios. Subsequently, the per circuit km costs are calculated for comparison. The following table presents the 33 kV line inspection costs estimated for the BAU scenario.

Table 4: Business-as-usual scenario for 33 kV line inspection

Cost Head (BAU scenario)		Description	Monthly rate (INR)	Total ckt km inspected* (km)	Per ckt km rate (INR)
1	Supervisor	Supervises the inspection	60,000	38.5	1,558
2	Linemen (2 nos.)	Inspect the line	80,000	38.5	2,078
3	Helper (1 nos.)	Assists the linemen while climbing the tower	20,000	38.5	519
4	Data collection and reporting (manual)	Collates the data and formulates the inspection report	25,000	38.5	649
5	Transportation	Vehicle used by the team for traveling to the site	60,000	38.5	1,558
Total monthly cost in BAU scenario (INR)			2,45,000		
Total per circuit km costs in BAU scenario (INR/km)			6,364		

**- assuming 1.75 circuit km per day for routine inspection and 22 working days in each month for urban areas*

Source: SAREP Analysis

33 kV line inspection costs estimated using drones are listed in table below:

Table 5: Drone rental or OPEX scenario of 33 kV line inspection

Cost Head (With Drone application)		Description	Monthly rate (INR)	Total ckt km inspected** (km)	Per ckt km rate (INR)
1	Supervisor	Supervises the inspection	60,000	66	909
2	Drone and Pilot rental	Drone Platform and Pilot operating from the ground	1,05,000	66	1,591
3	Payload rental	High-resolution camera and thermal infrared image	30,000	66	455
4	Automated data collection and reporting	Basic data processing, database storage and user interface	60,000	66	909
5	Transportation	Vehicle used by the team for traveling to site	60,000	66	909
Total per circuit km costs in drone application scenario (INR)			3,15,000		
Total per circuit km costs in drone application scenario (INR/km)			4,773		

***- assuming 3 circuit km per day for routine inspection and 22 working days in each month in urban areas*

Source: SAREP Analysis

It is evident from the cost estimation that saving of 25% can be achieved in O&M costs with deployment of rental drone for inspection.

Table 6: Scenario Comparison – BAU vs Rental or OPEX model for line inspection

Case	Scenario	Per ckt km rate (INR/km)	Benefit (%)
Case 1- Rental or OPEX model	BAU	6,364	25.00%
	Drone-based	4,773	

Case 2 - In-House or Capex Scenario

In this case, the assumption is that the utility will procure and operate the drone system. The BAU scenario remains the same as case 1. Accordingly, the cost of the CapEx-based drone operation scenario is presented in the following table.

Table 7: In-house drone or CAPEX scenario of 33 kV line inspection

Cost Head (With Drone application)		Description	Total cost*	Monthly rate** (INR)	Total ckt km inspected*** (km)	Per ckt km rate (INR)
1	Drone platform	Drone platform with payload	6,00,000	12,500	66	189
2	Operating and Maintenance cost	Charging of drones, wear, and tear during flights		40,000	66	606
3	Data management platform	Basic data processing, database storage and user interface	–	60,000	66	909
4	Supervisor	Supervises the inspection	–	60,000	66	909
5	Drone pilot	Drone pilot operating from the ground	–	55,000	66	833

Cost Head (With Drone application)		Description	Total cost*	Monthly rate** (INR)	Total ckt km inspected*** (km)	Per ckt km rate (INR)
6	Transportation	Vehicle used by team for travelling to site	–	60,000	66	909
Total per circuit km costs in drone application scenario (INR/km)						4,356

-Only actual outflow of cash is considered; **- assuming average life of drones of 48 months; *- assuming 3 circuit km per day for drone-based inspection and 22 days in each month in urban areas of Madhya Pradesh.*

Source: SAREP Analysis

With in-house drone, the payback period for utility is calculated from the monthly saving achieved utilizing drone application. Accordingly, the details are listed in table below:

Table 8: Drone Capex cost payback period

Description	
Saving using in-house Drone (INR/km)	2,008
Monthly Total Saving (INR) = (Total ckt km inspected* per km saving)	1,32,500
Payback Period (Months) = (Cost of Drone/Monthly Saving)	4.5

It is evident from the cost estimation that in-house or CAPEX model of drone applications can lead to a significant saving of 31.55% compared to the BAU scenario with a payback period of 4.5 months.

Table 9: Scenario Comparison – BAU vs in-house or CAPEX model for line inspection

Case	Scenario	Per ckt km rate (INR/km)	Benefit (%)
Case II- In house or CAPEX model	BAU	6,364	31.55%
	Drone-based	4,356	

Source: SAREP Analysis

This analysis is limited to hard costs incurred by the utilities during distribution line inspection and relates to the costs saved by faster drone service delivery. Other benefits such as better job quality and a safer work environment, are not quantified in this analysis.

Revenue Improvement of Discom

The benefit of drone monitoring is to prevent and predict maintainence activities to improve reliablity i.e improving SAIDI (reduced outages) with AI/ML based predictive prescreptive solution. As the outages would reduce, it will improve Discom's ability to supply power to the consumer for longer duration. The following table presents the centralized AI/ML solution deployment cost estimation.

Table 10: Assumptions and cost estimation for AI/ML predictive solution

Assumption Head	No. of Personnel	Monthly Base Salary (INR)	Number of Months	Total Expense (INR)
Supervisor	1	1,70,000	12	20,40,000
Assistant Engineer	2	1,00,000	12	24,00,000
Data Scientist/IT	2	1,20,000	12	28,80,000

Assumption Head	No. of Personnel	Monthly Base Salary (INR)	Number of Months	Total Expense (INR)
Annual Software Cost (INR)				30,00,000
Total Cost (INR)				1,03,20,000

Source: SAREP Analysis

Three scenarios of BAU vis-à-vis AI/ML based predictive prescreptive solution deployement are considered and benefit in terms of increased revenue due to improved SAIDI with solution deployment cost is estimated.

- In Case I, SAIDI improved by 20% for each urban circle
- In Case II, SAIDI improved by 40% for each urban circle
- In Case III, SAIDI improved by 60% for each urban circle

Table 11: Cost- Benefit Analysis- SAIDI improvement for domestic consumers

Case		Outage (Hrs)/Year	Availability (Hrs)/Year	Domestic consumption (MU)/Year	Yearly revenue (in Cr)	Benefit (in Cr) ****	Benefit (%)
Present Scenario	BAU	526*	8,234	15,707**	10,068***		
Case-1 SAIDI 20% Reduction	Software-based	421	8,339	15,908	10,196	128	1.3
Case-2 SAIDI 40% Reduction	Software-based	315	8,445	16,108	10,324	256	2.5
Case-3 SAIDI 60% Reduction	Software-based	210	8,550	16,309	10,453	385	3.8

-estimated from SAIDI for 11 months* (CEA, 2022); *- Domestic user consumption* (MPERC, n.d.); ****- assuming average billing rate of 6.41Rs/unit for domestic consumers* (MPERC, n.d.), *****Benefit= Yearly Revenue-Total cost of AI/ML Solution, MP urban feeders and domestic consumer consumption are taken into consideration for the analysis*

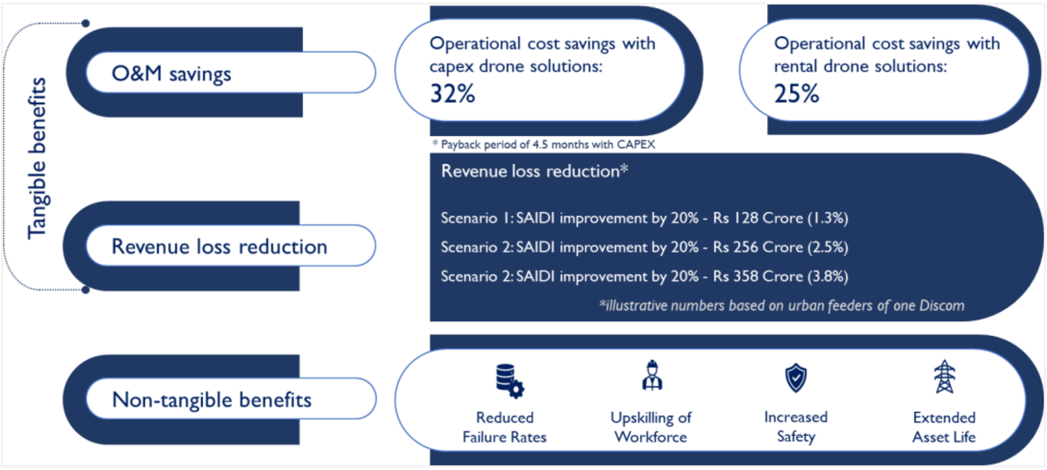
Source: SAREP Analysis

It is evident from the scenario cost estimation that deployement of AI/ML based predictive prescreptive solution lead to significant cost-benefit in terms of increased revenue when compared with the BAU scenarios.

- In Case I, with 20% improvement in SAIDI, revenue from domestic consumers is estimated to increase by 128 crores.
- In Case II, with 40% improvement in SAIDI, revenue from domestic consumers is estimated to increase by 256 crores.
- In Case III, with 60% improvement in SAIDI, revenue from domestic consumers is estimated to increase by 385 crores.

An illustrative summary of the cost-benefit analysis achieved through drone application is provided below in Figure 17.

Figure 17: Cost-benefit of drone application vis-a-vis BAU



For distribution utilities, network assets inspection through drone can significantly reduce O&M expenditure with quick and accurate identification of faults. Coupled with advanced AI/ML based analytical predictive solution, drone can further reduce the unplanned shut down. AI/ML based solution can suggest appropriate course of action based on the assessment of criticality of the issue and assist distribution utilities in making informed maintenance decision and planning the appropriate budget.

Priority Applications

Based on the study carried out for drone applications' use cases and cost-benefit estimation, Table 12 below lists the applications which are more relevant and can enhance the financial and operation performance of the distribution utilities if deployed and scaled up successfully.

Table 12: Drone applications prioritization for distribution utilities

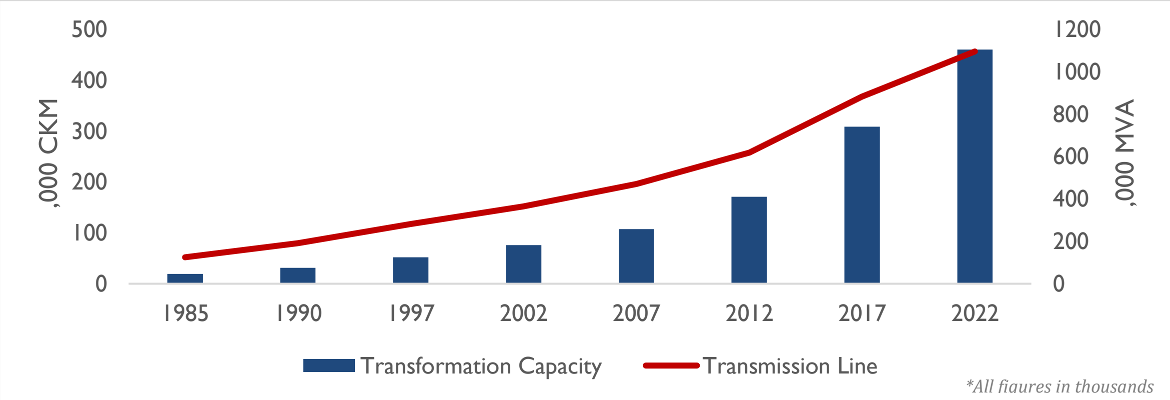
Drone Applications
Priority Applications
GIS Mapping
Distribution and Predictive Maintenance using AI/ML
Visual and Inspection of Assets
Theft Detection
Other Applications
Vegetation Management
Distribution Infrastructure Installation and Maintenance

Drone Applications in Transmission

4 DRONE APPLICATIONS IN TRANSMISSION

The transmission network in the country has increased rapidly over the years. For instance, from 1985 to 2022, the transmission capacity and transmission lines have increased by the rate of 9.2% and 6.2%, respectively (Figure 18) (PFC, 2020). While such a large capacity contributes to improved energy access, the reliability of the power system depends heavily on the quality of equipment, installation, construction, and how well O&M is conducted.

Figure 18: Growth of transmission capacity in the country from1985 to 2022



Source: (PFC, 2020); *Central Electricity Authority (CEA), 2022*

As power infrastructure expands and demand increases, the need for efficient O&M also grows. O&M, however, remains heavily dependent on manpower, making it both expensive and hazardous. O&M expenditure for distribution utilities in the country is around 19% of their total expenditure. During FY 2019, total O&M costs for 55 distribution utilities were recorded at INR 1.63 trillion (PFC, n.d.).

Manual inspections also entail low efficiency and limitations in reaching difficult locations. Transmission assets especially encounter these issues as, unlike conventional generation assets, they are often spread across large areas and hard to access terrain.

The O&M of transmission assets have opened trillions of rupees worth of market for the application of drones, which provide cost-effective, safe, and accurate assessment for routine predictive and preventive maintenance of such infrastructure. Use-cases for some of significant applications are as elaborated below:

Table 13: Use cases for drone applications in transmission network

	Application Area	Role Of Drone Applications	USE CASES
1	Routine Transmission Infrastructure Inspection	Reduced inspection time, save cost, and improved accuracy.	• The Scottish and Southern Electricity Networks (SSEN) Transmission, Scotland • TS-TRANSCO, Telangana
2	Line Corridor Inspection	Inspection of remote areas and difficult terrain.	• RTE, French energy transmission company
3	Emergency Management	Post-disaster inspections and surveys.	• Southern California Electric (SCE), U.S.

The following sub-sections elaborate on some of the drone applications and user cases in transmission O&M.

4.1 Routine Transmission Infrastructure Inspection

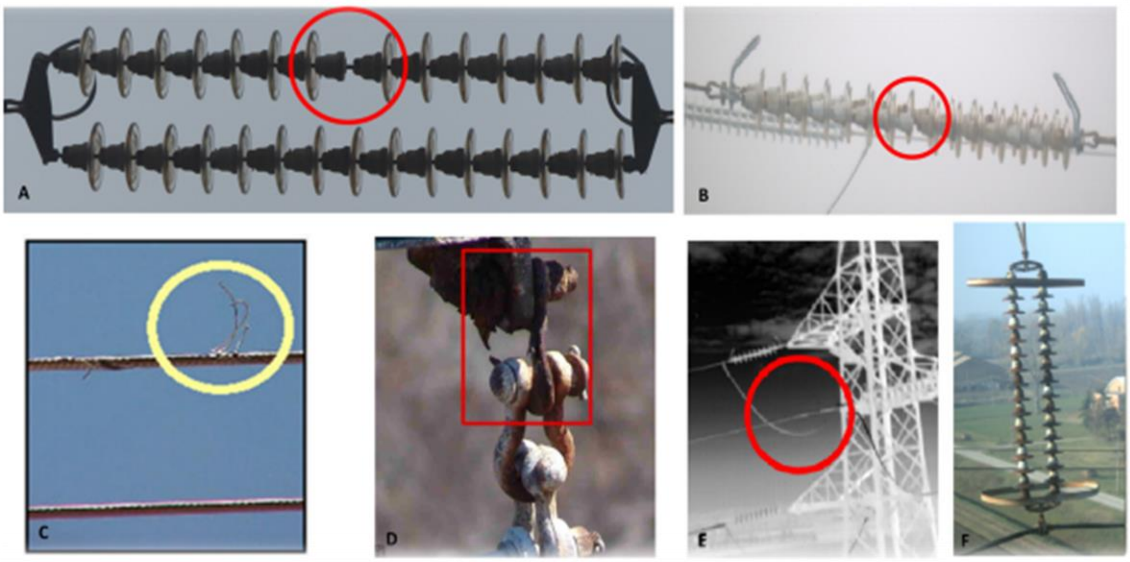
Drones can improve inspections of transmission infrastructure such as powerlines, tower structures, substations, and transformers at a lower cost while minimizing the risks. As an alternative to manned aerial vehicles such as helicopters, drones are safer, quieter, and more environmental-friendly and offer a viable option for conducting routine line patrolling in dangerous situations or hard-to-reach terrains.

The drone images are stored in a central database, generally a cloud-based system. The database also stores the standard design specifications of the transmission infrastructure elements such as towers, insulators, poles, conductors, transformers, etc.

The images are then processed using AI/ML-based system for a range of diagnostic analyses viz. corrosion detection in metal structures, identification of faults/hot spots/weak links in conductors, insulators, line accessories, wear and tear in tower components, and missing members/parts, if any, vegetation growth, etc.

Finally, the AI/ML system generates reports for the maintenance action required and optimal resource utilization plan. Videography of the transmission line corridors and the surroundings also provides terrain knowledge and results in easier planning of maintenance and post-fault repair activities.

Figure 19: A sample of common defects



Note: (A) missing plate along the insulator chain; (B) missing plate along the (rusted) insulator chain; (C) damaged cable strand; (D) hanging point, damaged by rust; (E) cable joints, which are more frequently affected by hot spots; (F) a chain of insulators, rusted
Source: Bushra Jalil, Giuseppe Riccardo Leone, Massimo Martinelli, Davide Moroni, Maria Antonietta Pascali and Andrea Berton; Fault Detection in Power Equipment via an Unmanned Aerial System Using Multi Modal Data; 2019

Case Study: Scotland

The Scottish and Southern Electricity Networks (SSEN) Transmission has been using drones since 2012. It deploys Cyberhawk's iHawk drone data collection platform to inspect and monitor over 11,500 transmission towers and almost 150 substations across the Scottish Utility Network. By using iHawk to capture and manage the data, strategic planning across the North of Scotland's transmission and distribution networks can be coordinated by the utility, even informing other utilities of planned developments. This, according to SSEN Transmission, has offered value as the visual data has supported multi-million-pound investment decisions.

Regular drone inspections and efficient data processing allow SSEN Transmission to identify issues early, so interventions can be focused on the most critical items before they fail. With the impact of Covid-19 pandemic at the start of 2020, SSEN could minimize the need for face-to-face contact between the maintenance teams and engineering staff due to no need for reliance on old paper-based systems.

Key Result

In an example of the platform and drones collaborating, a missing split-pin on an insulator fitting was identified during routine inspections, and a planned outage was made. The issue was thus resolved quickly, and a possible network failure was avoided.

Source: (CyberHawk, n.d.)

Case Study: India

The Telangana government recently announced that it had successfully completed a pilot project aiming to explore the use of drones for inspection of power lines and towers. The project sought to leverage drones and artificial intelligence (AI) to overcome limitations of manual inspections.

Telangana's Information Technology, Electronics and Communications (ITE&C) Department made in partnership with Transmission Corporation of Telangana, aerially inspected, monitored, and patrolled extra high tension (EHT) transmission towers, lines, and substations of TS-TRANSCO. A Hyderabad-based start-up named Centillion Networks deployed its capabilities in using drone technology. The images for the pilot were captured with high-resolution 4K cameras and image recognition software based on artificial intelligence. Using this, EHT transmission line towers for 220 KV Chandrayagutta Ghanapur line, 220 KV Shivarampally - Gachibowli line, 132 KV Minpur - Jogipet line, 220 KV Budidampadu - Waddekothapally line and another ten towers were inspected. The inspection of each tower was conducted within twenty minutes.

The locations were surveyed using drones and the tower inspections were conducted by Centillion Networks in presence of officials from TS-TRANSCO and the ITE&C department. The project aimed to leverage drones and artificial intelligence (AI) to overcome the limitations of manual tower inspections. The pilot demonstrated that use of drones can speed up activities and reduce risks to human lives in various situations. The tower inspections also yielded accurate data and analysis implying that manual inspections could be substantially reduced. In addition, automated inspections reduced man-hours and resulting costs by nearly half. Post this pilot, TS-TRANSCO may scale up the drone surveillance project.

Key Result

Reduction in man-hours and costs by approximately 50 per cent.

Source: (Pandey, 2021)

4.2 Predictive Maintenance Using AI/ML Technologies

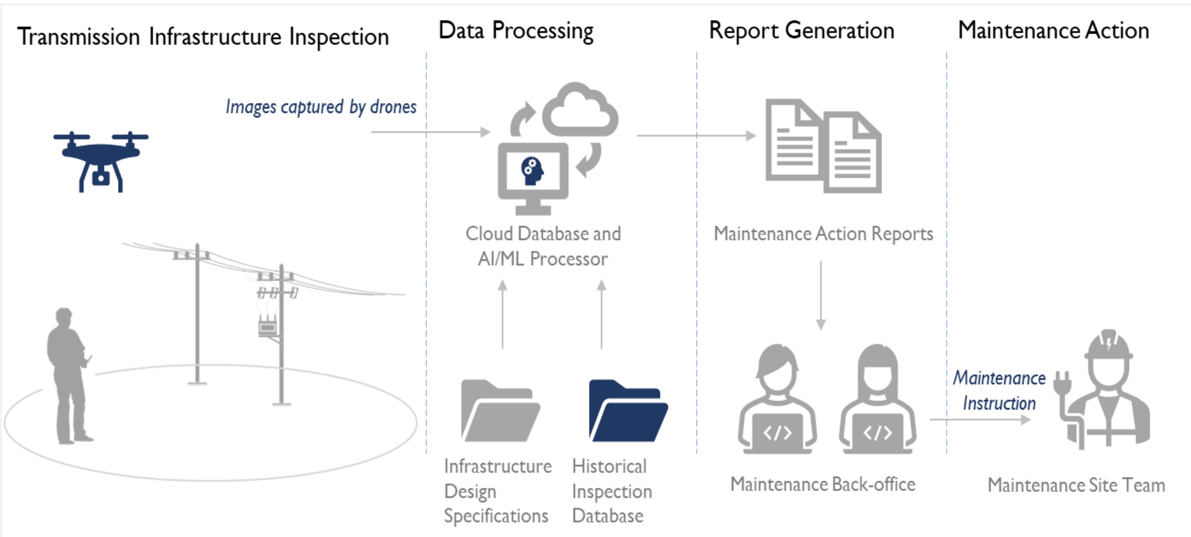
Predictive maintenance (Eagle CMMS, n.d.) planning commences with monitoring the condition of the plant, equipment, and installations that comprise the transmission infrastructure, using drones at periodic and pre-determined intervals. The exercise primarily monitors the health of the electrical network along with line accessories and components in use and facilitates early detection of incipient faults from the evidence gathered during such inspections.

Using AI/ML-assisted data analytics, pattern recognition insights are developed to implement asset-specific predictive maintenance schedules that would arrest the onset of faults and network failures in a pre-emptive manner. The data can be further integrated with IT-enabled asset management practices to develop a maintenance regime covering the life cycle of a capital asset.

Drone inspections capture high-resolution network imagery and related performance data of weak spots that would expose an asset or component to potential failure. Trends that can be assigned to a network asset or component are visible when such information is gathered over a period and can be further processed by applying AI/ML tools to establish historical patterns, and their progression and subsequently undertake prognostic analysis for arresting and reversing these occurrences.

Based on the evidence-driven and location-specific intelligence collated, corrective actions to improve planning and design at the network, asset, and component level can be laid out with a reasonable degree of confidence. Additional insights can be gained by pairing with software that enables the conversion of point measurements undertaken by drone inspections into 3D models and facilitates visualization of design modifications and upgrades necessary to improve network performance at the granular level.

Figure 20: Predictive maintenance of transmission infrastructure using drones



4.3 Line Corridor Inspection

Routine transmission infrastructure inspection is conducted thoroughly for each component of the infrastructure being inspected up to the level of nuts, bolts, and joints by taking high-resolution visual and thermal images.

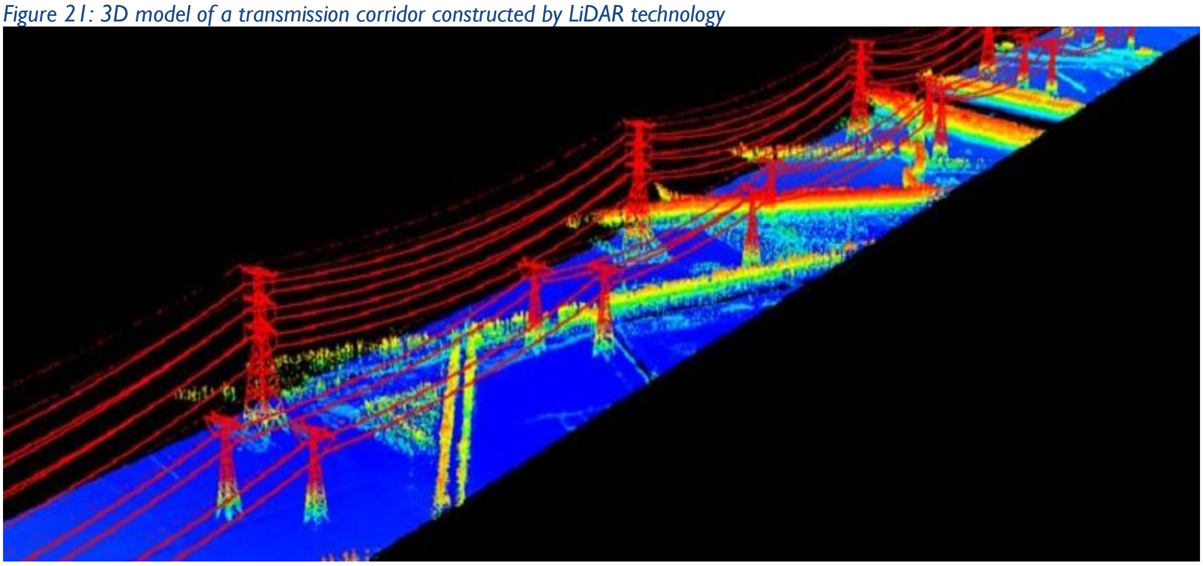
Line corridor inspection, on the other hand, is the fast scanning of the line corridor to identify any potential risk and danger underneath or nearby the power line. Such potential risks can include any foreign objects on wire or the tower, vegetation, unexpected construction, or structure.

Due to the nature of inspection required, compared to routine T&D infrastructure inspection where rotorcrafts are generally used, fixed-wing drones are more suitable for line corridor inspection.

With the addition of Light Detection and Ranging (LiDAR) and multispectral sensors as payload, imagery derived from drone inspections can also be utilized to generate three-dimensional (3D) models of the line corridor and the landform, including the surrounding structures, buildings, and vegetation.

These 3D models serve as the base for simulating the impact of extreme weather conditions, vegetation growth, and natural calamities affecting the line performance that are particularly useful for inspection of hard-to-reach terrains, disaster-prone areas, and mobilizing action plans, including crew deployment, on the occurrence of a fault.

Figure 21: 3D model of a transmission corridor constructed by LiDAR technology



Source: (Ball, 2021)

Case Study- France

French energy transmission company RTE has to conduct maintenance and repairs for over 100,000 km of electricity power lines, constituting the biggest network in the country. Monitoring the entire network to spot vegetation encroachment is a critical task to their core activities. To improve productivity and prune costs, the company shifted from helicopters to drones and purchased Delair's mapping and digitizing solution for power line corridors along with the DT26 drone. This long-range fixed-wing UAV is Beyond Visual Line of Sight (BVLOS) certified by the French Civil Aviation Authority (DGAC), contains a LiDAR sensor, and is suited for long-distance corridor mapping of power lines.

LiDAR data is used to create Digital Terrain Models and Digital Surface Models of the power line corridors. The models are inputted into maintenance and engineering tools at RTE to perform different calculations to identify exactly where to prune the lines to meet the safety clearance zones around the lines. Flying the drone requires prior preparation with the pilots having to locate a suitable spot for take-off and landing which not too far away from the lines, while avoiding flight restricted areas.

The DT26 flies a 30-km round-trip, starting from the middle and flying 15 km on each side. The associated LiDAR is self-sufficient to perform the 60-km long flights for RTE's needs.

Source: (DelAir, n.d.)

4.4 Emergency Management for Grid Resilience

Drones can be used to conduct post-disaster inspections and surveys in situations such as earthquakes, landslides, and wildfires, particularly where some areas may not be accessible. Deployment of drones as part of disaster management plans enables the utilities to undertake asset and network surveillance in remote areas, assess climate-related risks affecting the performance of critical installations, and provide resilience plans to withstand weather-related events. Utilities are thus able to: i) keep public and employee safety as a top priority; ii) save time in responding to natural disasters; and iii) restore outages with faster access to reliable data (Huffman, n.d.).

Drones can be utilized to spot vulnerabilities in the electrical network and installations that require emergency responses; they could play a major role in `smart grid' (National Smart Grid Mission, n.d.) operations by enabling both geographical visualization and situational awareness based on instant data access and as relay towers when communication links break down due to natural disasters or cyberattacks.

Furthermore, foreign objects, like kites, balloons, plastic bags, etc., can be removed from facilities using drones equipped with lasers, flame guns, or electric wires (Yue, 2021).

Figure 22: Emergency management using drones

Source: https://www.123rf.com

Case Study- United States of America

Southern California Electric (SCE) in the U.S. has included drones as part of their emergency action plans as well as overall maintenance program. While drones have quickly become an essential tool for the utility to inspect assets and mitigate wildfire risks it is also deploying aerial surveillance for dam safety. SCE's hydroelectric system has 83 dams stretching from Catalina Island to Big Creek near Fresno.

Drones efficiently deliver high-resolution images that identify minor issues like leakages and cracks before they become major problems. Images are further enhanced through technologies like LiDAR and 3D mapping.

Drones also eliminate safety risks involved in worker inspections that require specialized equipment and training to physically access steeply sloped areas of a structure. Amid the COVID-19 pandemic, inspections could be done via drone instead of having people go out in groups.

Together, the high-tech drones and cameras present continuous situational awareness of dams that is particularly handy during earthquakes in the area.

Source: (Netter, 2020)

4.5 Corona Detection

Corona discharge detection is an essential part of power lines inspection. The equipment currently employed includes infrared thermal imagers and ultraviolet (UV) cameras which can accurately inspect, detect, and analyze the position and strength of the corona discharge. Combined with drones and referenced with GPS, UV detection offers images that isolate the location of the corona discharge with greater precision and consistency, thereby enabling. Remote monitoring of power lines and fault detection in a cost-effective manner.

Figure 23: Corona discharge on an insulator of a high-voltage line

Source: http://www.electrician.com.ua/posts/1597

4.6 Cost-Benefit Analysis

The following methodology was adopted for the cost-benefit analysis for drone application in transmission.

- Scenario development
- Data collection
- Estimation of costs
- Analysis of cost-estimates

Scenario Development- Transmission

In the Indian context, transmission companies are among the early adopters of drone technologies and there are multiple use-cases available for the application of drones in powerline inspection. One such situation was considered for this analysis. For the inspection of a 400 kV transmission line the following assumptions considering:

Table 14: Assumptions for cost-benefit analysis for transmission line

Assumption Head	BAU Scenario	Drone Application
Team	1 Engineer, 2 linemen, 1 helper	1 Engineer, 1 drone pilot
Routine inspection/day	6 circuit km	12 circuit km
Detailed inspection/day	2 circuit km	4 circuit km
Inspection Data	Manual data collection and reporting	Automated data collection and processing of reports by cloud-based applications
Transport to site and allowances	Same cost/day for both scenarios	
Finance cost	The costing is activity-based and includes the interest and financial cost for both the scenarios	

Two cases of procurement of drone applications were considered under each scenario.

- Case 1 – rental or OPEX model
- Case 2 – in-house or CapEx model

Data Collection

The SAREP team held meetings with multiple drone service providers that are active in the Indian power sector, to validate the assumptions and assess the costs involved in both the BAU scenario and when the drone was used. The benchmarking costs for O&M of transmission lines, approved by regulatory commissions and the recent tenders floated by transmission utilities, were also assessed to estimate the costs.

Cost Estimation

Two scenarios of BAU vis-à-vis drone operations employing the OPEX, i.e., rental model (case 1) and CapEx, i.e., in-house model (case 2), were developed.

Case 1 – Rental or OPEX model

Details of rental, salaries, and other monthly expenses are available and are considered for both scenarios. Subsequently, the per circuit km costs are calculated for comparison. The following table presents the powerlines inspection costs estimated for the BAU scenario.

Table 15: Powerline inspection costs- BAU scenario

Cost Head		Description	Monthly rate (INR)	Total ckt km inspected* (km)	Per ckt km rate (INR)
1	Supervisor	Supervises the inspection	65,000	120	542
2	Linemen (2 nos.)	Inspect the line	80,000	120	667
3	Helper (1 nos.)	Assists the linemen while climbing the tower	25,000	120	208

Cost Head		Description	Monthly rate (INR)	Total ckt km inspected* (km)	Per ckt km rate (INR)
4	Data collection and reporting (manual)	Collates the data and formulates the inspection report	25,000	120	208
5	Transportation	Vehicle used by the team for traveling to the site	60,000	120	500
Total monthly cost in BAU scenario (INR)					255,000
Total per circuit km costs in BAU scenario (INR/km)					2,125

**- assuming 6 circuit km per day for routine inspection and 20 working days in each month*

Source: SAREP Analysis

The following table presents the powerlines inspection costs estimated using drones.

Table 16: Powerline inspection costs- drone application (Rental or OPEX scenario)

Cost Head		Description	Monthly rate (INR)	Total ckt km inspected** (km)	Per ckt km rate (INR)
1	Supervisor	Supervises the inspection	65,000	240	271
2	Drone pilot	Drone pilot operating from the ground	35,000	240	146
3	Drone rental	Quadcopter (Four rotors)	125,000	240	521
4	Payload rental	High-resolution camera and thermal infrared imager	30,000	240	125
5	Automated data collection and reporting	Basic data processing, database storage and user interface	60,000	240	250
6	Transportation	Vehicle used by the team for traveling to site	60,000	240	250
Total monthly cost in BAU scenario (INR)					375,000
Total per circuit km costs in drone application scenario (INR/km)					1,563

**- assuming 12 circuit km per day for drone-based inspection and 20 days in each month.*

Source: SAREP Analysis

Case 2 – In-house or CAPEX model

In this case, the assumption is that the utility will procure and also operate the drone system. The BAU scenario remains the same as case 1. Accordingly, the cost of the CapEx-based drone operation scenario is presented in the following table.

Table 17: Powerline inspection costs- drone application (In-house or CapEx scenario)

Cost Head		Description	Total cost*	Monthly rate** (INR)	Total ckt km inspected*** (km)	Per ckt km rate (INR)
1	Drone platform (quadcopter) with payload	Quadcopter (Four rotors) with High-resolution camera and thermal infrared imager	10,00,000	20,833	240	87

Cost Head		Description	Total cost*	Monthly rate** (INR)	Total ckt km inspected*** (km)	Per ckt km rate (INR)
2	Operating and Maintenance cost	Charging of drones, wear and tear during flights		40,000	240	167
3	Data management platform	Basic data processing, database storage and user interface	–	60,000	240	250
4	Supervisor	Supervises the inspection	–	65,000	240	271
5	Drone pilot	Drone pilot operating from the ground	–	35,000	240	146
6	Transportation	Vehicle used by team for travelling to site	–	60,000	240	250
Total per circuit km costs in drone application scenario (INR/km)						1,170

-Only actual outflow of cash is considered; **- assuming average life of drones of 48 months; *- assuming 12 circuit km per day for drone-based inspection and 20 days in each month.*

Source: SAREP Analysis

Scenario Comparison

It is evident from the scenario cost estimation that drone-based applications lead to significant cost-benefit when compared with the BAU scenarios.

- In Case I, the drone-based powerline inspection is estimated to reduce the costs by 26.4%
- In Case II, the drone-based powerline inspection is estimated to reduce the costs by 44.9%

Table 18: Cost-benefit analysis- Drone (Transmission)

Case	Scenario	Per ckt km rate (INR/km)	Benefit (%)
Case I- Rental or OPEX model	BAU	2,125	26.4%
	Drone-based	1,563	
Case II- In-house or CapEx model	BAU	2,125	44.9%
	Drone-based	1,170	

Source: SAREP Analysis

This analysis is limited to hard costs incurred by the utilities during powerline inspection and relates to the costs saved by faster drone service delivery. Other benefits such as better job quality and a safer work environment, are not quantified in this analysis.

As per studies, in comparison to manual inspection (BAU scenario) (UAV Huanqiu, 2018), drone-based inspections are better at identifying potential risks and defects. Therefore, it is reasonable to expect that drone-based powerline inspection can help reduce the outage time and the associated costs.

The adoption of drone applications by the Indian power sector is in its early stages. The drone ecosystem is expected to evolve rapidly, and service costs will reduce further. Discussions with drone service providers have revealed that initially, the rental or OPEX model is the preferred model for procuring drone services. However, as the technology matures, most utility service providers are likely to adopt the CapEx model. For example, the Jalgaon division of the Maharashtra State Electricity Transmission Company has already procured the M210 drone series for inspection of powerlines and other activities. Other transmission companies in the country are also expected to use drone technology, either on their own or through drone solution providers.

Priority Applications

Based on the study carried out for drone applications' use cases and cost-benefit estimation, Table 19 below lists the applications which are more relevant and can have higher impact on the financial and operation performance of the transmission utilities:

Table 19: Drone applications prioritization for transmission utilities

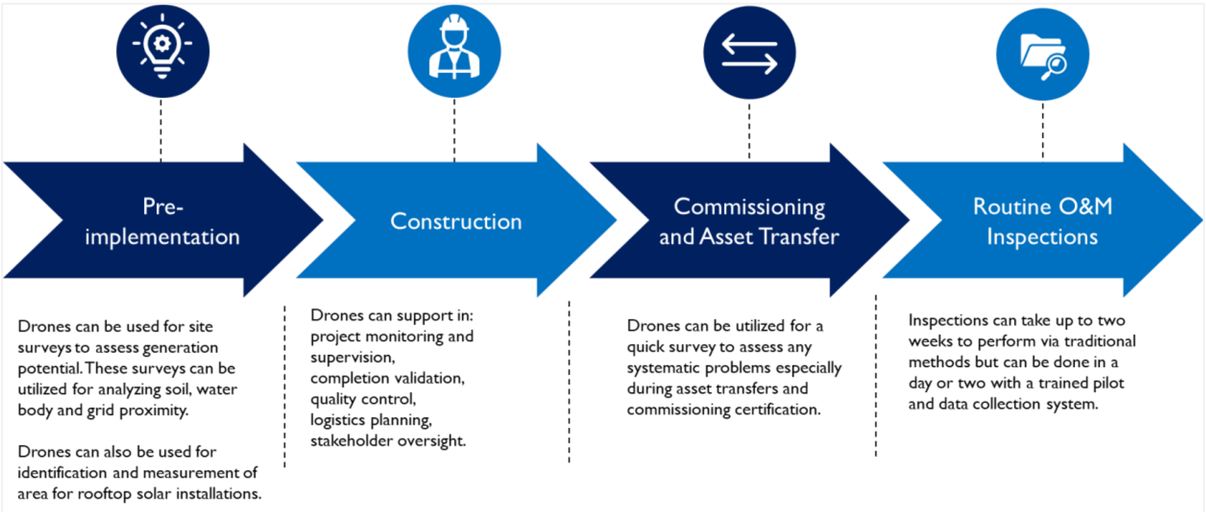
Drone Applications
Priority Applications
Line Inspection
Corona Detection
Routine Transmission Infrastructure
Predictive Maintenance using AI/ML Technologies
Other Applications
Vegetation Management
Emergency Management

Drone Use Cases in Clean Energy Projects

5 DRONE USE CASES IN CLEAN ENERGY PROJECTS

Drone applications can be utilized over the entire lifecycle of solar and wind projects beginning from site development surveys, construction, and the O&M phase to asset transfer. The following figure provides an overview of applications during different phases of clean energy projects.

Figure 24: Drone applications for different phases of clean energy projects



5.1 Applications for Solar Projects

The continuous growth of the solar industry brings an ever-expanding base of solar installations. A solar panel's lifespan is estimated to be 20 years, which makes quality assurance essential. A failure-free operation of the panels is necessary for efficient power generation, long life, and a high return on investment. Over time, solar panels may develop defects that can cause efficiency to decline and if left unattended, can result in fire. But these defects can be easily fixed if detected in time.

Traditionally, solar inspections were conducted on foot using handheld infrared cameras, which required long and tedious surveys. An alternate method traditionally involved solar farms surveys conducted by low-flying manned aerial flights using thermal cameras. Besides being time-consuming and expensive, these methods also place employees at risk. Contrary to traditional inspection methods, drones mounted with infrared cameras offer a quick and cost-effective way to keep solar farms running at optimal efficiency and maintenance by detecting malfunctions faster and enabling swift repairs. Drone surveys can reduce inspection costs by half, allowing businesses to improve efficiency and maintain operations at a higher level.

Drones equipped with visual and infrared cameras can monitoring key failure points, and detect the abnormal conditions of photovoltaic panels, such as the presence of dirt, cracks, wear and tear, and the impact of shading or overheating. Drones can locate local hot spots, differentiate them using the AI/ML technologies and help the maintenance team optimally plan for cleaning or replacing the panels.

Additionally, in remote areas and unapproachable terrain, drones equipped with robotic disc pads and brushes can be remotely navigated to clean the solar panels, thereby obviating human interventions.

Drones offer ease of identification of rooftop areas for solar installations by taking high-resolution aerial images, thereby reducing manual deployment as well as measurement errors and enabling realistic assessment of solar generation potential, selection of the solar modules, and Balance of System (BOS) equipment, along with their compatibility to adjacent buildings and structures in the neighborhood.

Figure 25: Solar PV plant inspection using drones

Source: https://www.123rf.com

Figure 26: Hotspot detection in solar PV panels using infrared imaging

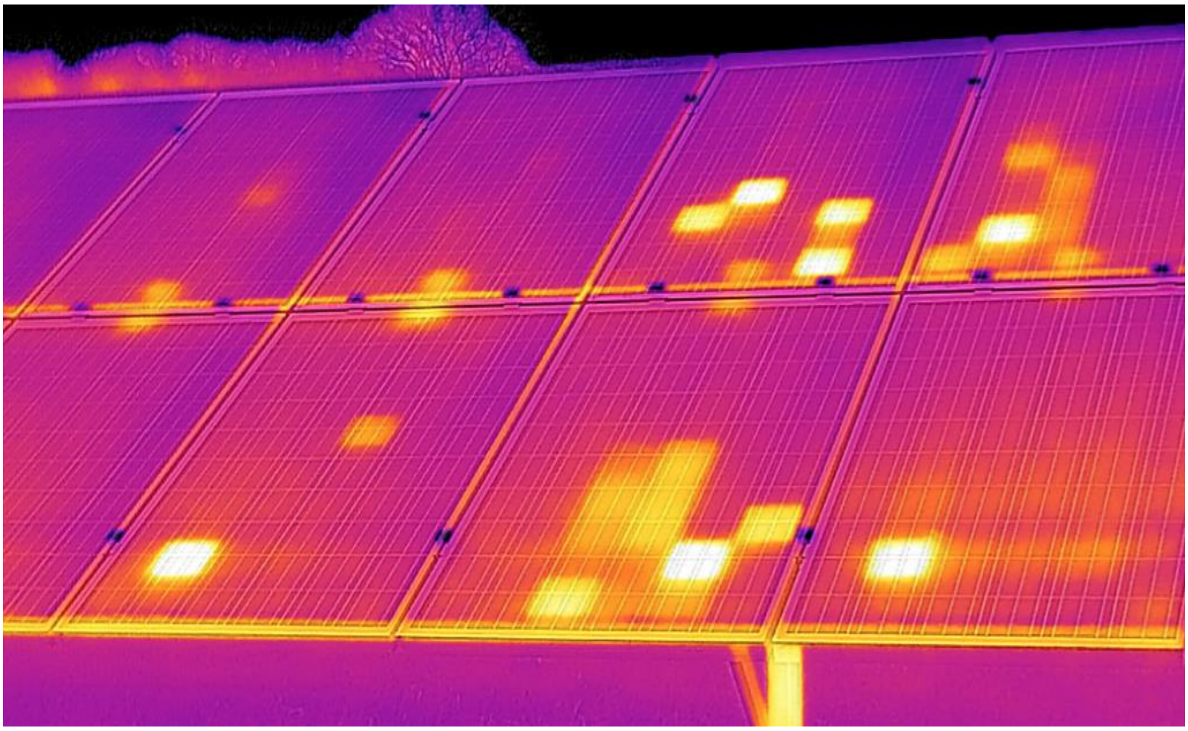


Image source: (VCT Group, n.d.)

Case Study- India

Pace Power Systems Pvt Ltd., an independent power producer (IPP) in southern India, partnered with ABJ Drones to perform a pilot on an aerial inspection of a 10 MW solar installation. A skilled drone pilot along with a DJI M210 drone mounted with an optical plus thermal payload was commissioned. In addition to 105 hotspots, nine bypass diode activations and six bypass diode failures were discovered.

Two flights, operating over 40 minutes, enabled the pilot to gather raw data, which was then processed and submitted to Pace Power. The findings of this inspection were rapidly actionable for asset managers.

Despite the installation being relatively new, 105 modules with hotspots were discovered, along with nine modules with bypass diode activation, and six with bypass diode failure. In addition to identifying problems, ABJ also suggested some easy-to-implement rectifications. A marked-up site diagram was prepared that identified defects by panel number using an easy-to-follow legend.

As opposed to a 14-hour conventional inspection of the installation, ABJ's inspection took just about an hour, at 40% cost of a regular inspection. The accuracy of the result was also pegged at 99.85%. ABJ's report enabled Pace Power Systems to undertake the necessary repairs in time.

Source: (ABJ Drones, 2020)

Case Study- Canada

iSolara, an Ottawa-based solar power design and installation company is using Phantom 4 drone along with mapping software called DroneDeploy to help visualize, measure and design their largest projects.

With DroneDeploy's built-in measurement tools, initial rooftop measurements can be done with the click of a button, which immediately saves several hours spent measuring hand. This also made the process safer, as it reduced the amount of time spent on the roof.

With better imagery and a three-dimensional model that can easily be manipulated, the entire design process for a project was reduced from 10 man-hours to just under three hours, representing a time savings of 70%. The availability of aerial mapping imagery is a value-addition for installation contractors and project owners—a feature that also drove up iSolara's sales.

Source: (Drone Deploy Blog, 2017)

5.2 Applications for Wind Projects

The most sought-for drone application for wind projects is the routine inspection of the wind turbines, particularly the turbine blades. These blades, often large in size, ranging from 60 to 100 meters, may develop structural problems due to continuous exposure to harsh environments, resulting in minute cracks or deformities that are not visible to the naked eye.

Routine drone inspection of the wind turbines is done to monitor critical areas of turbine failure, such as malfunction of blades, damage to blade coating, surface cracks, blade deformation, etc., as well as identify bolt breakage, damage, or corrosion affecting the tower structure.

Images captured by high-resolution cameras and interpreted by AI/ML tools help build digital footprints of the affected parts, spot critical structural problems and support the O&M team to develop proactive maintenance and repair plans. Importantly, close-up 3D images of turbine blades can be developed to ascertain defects/imperfections without stopping the turbines.

Figure 27: Wind turbine inspection using drones

Source: https://www.123rf.com

Case Study- Spain

Drone technology has helped Spanish electricity company Iberdrola to inspect wind farms, making it possible for them to detect structural incidents in turbine blades and serve as a guide during maintenance. This has saved considerable costs and increased safety of operations for the company. As of 2018, Iberdrola was inspecting 12,000 turbines worldwide with the help of drones.

The company has deployed the Arachnocopter, a multirotor folding helicopter, that has helped in the inspection of wind turbine blades. It is equipped with high-definition cameras and other sensors and is capable of generating, after just seven minutes of flight, an internal X-ray of a turbine's blades detecting structural problems, such as corrosion or hot spots.

The associated software allows the Arachnocopter to process and transmit digital maps created in real time, thereby helping technicians to locate defects easily via their mobile phone.

This raises efficiency during wind farm maintenance inspections, reduces downtime and achieves far superior level of detail that compared with traditional methods.

In 2021, the Arachnocopter was used for the digital analysis of offshore wind structures, improving the inspection of wind farms during their operational and maintenance phases. Use of drones has led to cost savings, fewer accidents, and an increase in equipment reliability.

Source: (Iberdrola, n.d.)

Priority Applications

Based on the study carried out for drone applications' use cases, Table 20 below lists the applications which could be significantly beneficial for clean energy projects:

Table 20: Drone applications for clean energy projects

Drone Applications
Priority Applications
Routine O&M Inspection
Construction Project Monitoring and Supervision
Other Applications
Pre-implementation/construction site survey
Drone surveying for systematic problems in commissioning and asset transfer

Drone Use Cases in Conventional Generation and Construction

6 DRONE USE CASES IN CONVENTIONAL GENERATION AND CONSTRUCTION

Drones offer easier, safer, and faster visual inspection giving their application an edge for thermal inspection of conventional power plants as well as in construction monitoring. There are multiple use-cases of successful deployment of drone applications for inspection of thermal, nuclear power plants and their monitoring during the construction phase. The following sections list some of these cases.

6.1 Applications for Conventional Generation

Power plants are using drones to inspect dams and critical power generation equipment including firing ducts, catalysts, silencers, tube panels, stack dampers, baffles, heat recovery steam generators, etc. Further, drones can be used for emergency inspections or in areas that are hazardous or difficult to reach.

Multirotor UAS can hover and hold a position while the operator moves the camera to focus on interest points or zooms to investigate potential concern areas. Photogrammetry software and overlapping photos can be used to create 3D point clouds and terrain models for analysis and design. The UAS is utilized for several purposes including volumetric surveying, topographic mapping; structure condition assessment; change detection; and flood hazard mapping.

Case Study- India

State-owned power generator NTPC Ltd. collaborated with Garuda Aerospace for its drones in 2021 to detect encroachments in its hydro power project areas, check for landslides, and identify leakages from reservoir/dam and wet spots.

NTPC will also use the drones to identify illegal mining/unlawful intrusions, boundary encroachments and detection of any overgrown vegetation affecting solar power generation, among other uses. The state-run company will deploy Remotely Piloted Aircraft System (RPAS) for carrying out research and inspection activities at its Vindhyachal Super Thermal Power Station, Madhya Pradesh, Gadarwara Super Thermal Power Plant, Madhya Pradesh, and Sipat Super Thermal Power Project, Chhattisgarh.

At its facilities, NTPC will use drones for terrain mapping, stockpile volumetric analysis, aerial inspections, and other purposes. The data provided by this method will be of high quality, high accuracy and obtained at a fraction of the cost of traditional methods.

Source: (SME Times, 2021)

6.2 Routine Inspection of Leakage in Nuclear Reactor

The advent of UAV technology has brought both opportunities and challenges for nuclear security. With illegal sightings increasing over nuclear plants, drones pose security challenges to this class of infrastructure and a threat to national security. Illicit drone flights over Sweden's (Singh, 2022) nuclear power projects and the monarch's palace are recent examples of major concerns. But drones also present solutions with great benefits for this industry. UAVs help with tracking and monitoring nuclear facilities through patrols and providing timely information to respond to threats. Some nuclear facilities also deploy drones for routine inspections and monitoring. This is a very beneficial application that minimizes human exposure to unnecessary radiation. Often underground tank-room inspections take 2-3 people, clad in radiation-protection gears. In case of leaks, the inspection team could be at risk of exposure.

Case Study- Inspection of Nuclear Power Plant *(undisclosed location)*

Swiss drone operator Flyability has a collision-tolerant Elios UAV that has been used at a major nuclear power plant inside inaccessible spaces of a reactor building.

When Flyability's customer has to carry out leak detection without drones, they have to reduce plant output to a mere 20% to make it humanly possible. The powering down process takes six hours and the same time to get back to full generation.

To inspect the underground tank rooms, operators flew Elios down the ladder to the rooms while remaining above in a low dose area. The Elios flew inside the room gathering a video of the entire space for evaluation later. An operator retrieved the drone at the top of the ladder using only a glove for protection against potential contamination. The drone also flew to 20 feet deep in another area to inspect a suspected leak. The inspectors later found that the information gathered by the drone was more comprehensive than what was done traditionally. It removed the need for the inspection team to climb down into the tank rooms and also brought down the inspection time from 1.5 hours (manually) to 15 minutes (using the drone).

The drone saved the customer 12 hours of powering up and down, thereby saving $456,000 from just one round of inspection.

Source: (FlyAbility, n.d.)

6.3 Construction and Progress Monitoring

Drones can be used from the bidding phase to cover the entire construction lifecycle, starting with a feasibility study, tendering, and progressing to detailed surveys, habitation analysis, project delivery, and completion. Some activities where drones can be used include:

1. Topographic mapping and surveying
    - Even before the launch of many construction projects, a topographic survey of the site is required to understand the environment in which the project will take place. Digital Terrain Models (DTMs) and Digital Surface Models (DSMs) (Innoter.com, n.d.) of a site generated with drone data can show possible drainage points, changes in elevation, and other factors that can assist in selecting the best locations for building, digging, or storing materials.
2. Progress monitoring
3. Maintenance of structures
4. Transportation of goods

Case Study- India

Sterlite Power has employed drone applications in different phases of constructing a transmission project and has listed out several benefits through this. In the project-bidding phase drones help with topographic surveys. This makes it easy to obtain visual imagery and creating a 3D model of the entire line. This helps in chalking out the optimal route, obtaining elevation and contour data and helps in the right of way mapping.

Drones also help in the timely mapping of construction activities using imagery, as monitoring is possible in remote and inaccessible locations such as tower heights. They are also useful in creating an environment of caution and safety among the workers on-site as they can be closely monitored remotely.

Finally, drones can be used for habitation analysis, as they generate more accurate pictures as compared to images gathered through satellites.

Sterlite Power deployed drones for stringing conductors in Kerala across the Shoranur junction railway station without shutting down power. In addition to saving time and cost, the railway operators and commuters were not inconvenienced. In fact, using drones to string conductors on transmission lines is making reconductoring efficient and more environmentally friendly. This task, which earlier required 2 days with 18-20 workers, can now be done within 20 mins and 2-3 people.

Sterlite Power announced acquiring a minority stake in 2016 in US-based drone service company Sharper Shape to bring its automated inspection and maintenance planning services for infrastructure asset owners.

Source:

1. (Sterlite Power, n.d.)
2. (Sterlite Power, 2020)

6.4 Emission Monitoring Using Drones

Emissions monitoring has become a critical activity for the industrial sector that emits different kinds of pollutants and has also become vital for scanning air quality levels systematically. With countries committing to carbon-neutrality targets and the general push towards environmental conservation, drone applications are becoming increasingly relevant for emission monitoring and are used to comply with environmental laws. Now multiple applications to measure the pollution content of ambient air, including urban air quality networks, industrial emission monitoring, safety monitoring, roadside monitoring, and air quality research, among others, have emerged. This is primarily because air pollution/emissions are difficult to monitor with conventional means of observation and rudimentary equipment in the atmosphere.

Case Study- Norway

Norway-based drone service provider, Nordic Unmanned, offers UAVs for measuring Sulphur emissions and ensuring compliance with regulations in the shipping sector.

Most ships run on heavy fuel oil, which causes large emissions of Sulphur Oxides (SO_X). These emissions cause air pollution, acid rain, ocean acidification as well as respiratory and other diseases in humans.

Drones operated by Nordic Unmanned are equipped with sensors that detect and measure levels of Sulphur Dioxide (SO_2), Carbon dioxide (CO_2) and Nitrogen oxides (NO, NO2) in ship exhausts. This allows for remote calculation of a ship's fuel composition outside of the port. If measurements are above the stipulated limit, the ship's port of call gets a notification to proceed with further fuel sampling. This helps in enforcing maritime environmental guidelines for SO2 emissions.

Using drones for emissions offers accurate results even from remote areas where human surveillance is not possible.

Source: (The Explorer, n.d.)

Priority Applications

Based on the study carried out for drone applications' use cases, Table 21 below lists the applications which can have higher impact on the conventional generators:

Table 21: Drone applications for conventional generators

Drone Applications
Priority Applications
Routine Inspection
Emission Monitoring
Other Applications
Construction Project Monitoring and Supervision
Vegetation

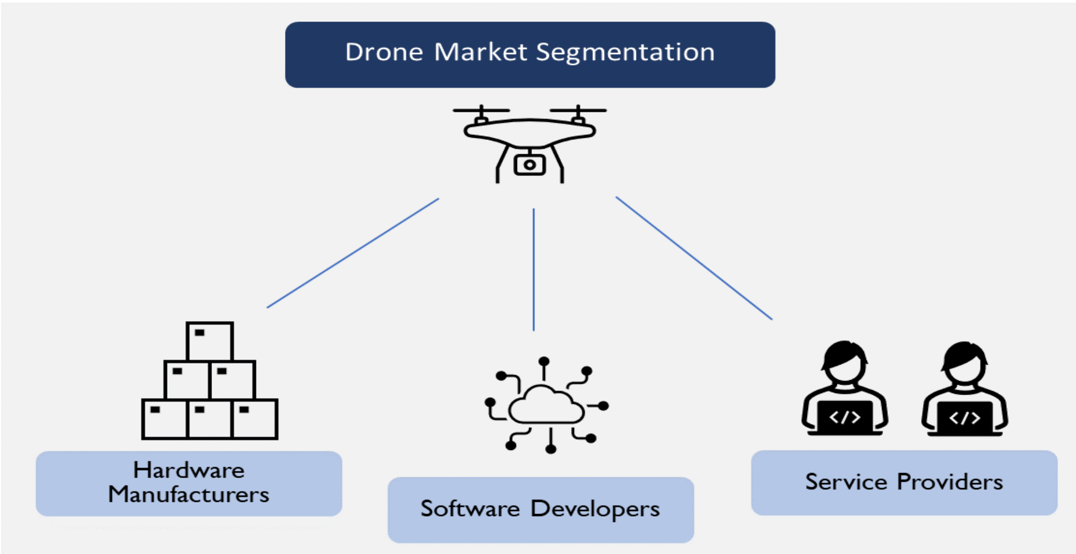
Drone Market Landscape

7 DRONE MARKET LANDSCAPE

Historically, drones have been used by the armed forces for surveillance and reconnaissance in unknown or hostile territories to track enemy movements, conduct border patrols, monitor emergencies, and search and rescue missions. The use of drones for commercial purposes is barely a decade-old phenomenon, but the shift has been metamorphic because of their applications in different sectors. Amazon Inc.'s founder Jeff Bezos' comment stating that his company wanted to test package delivery using drones back in 2013 was one of the most famous instances when the world noticed the potential of this technology for commercial use. According to ABI Research, the commercial drone market was valued at US$ 9.5 billion in 2020 and is expected to grow to US$ 92 billion by 2030, of which 70% of revenue will be from the commercial sector (US$63 billion) (Onag, 2020).

The drone industry can be broadly divided into three segments - drone hardware manufacturers, software providers, and service providers.

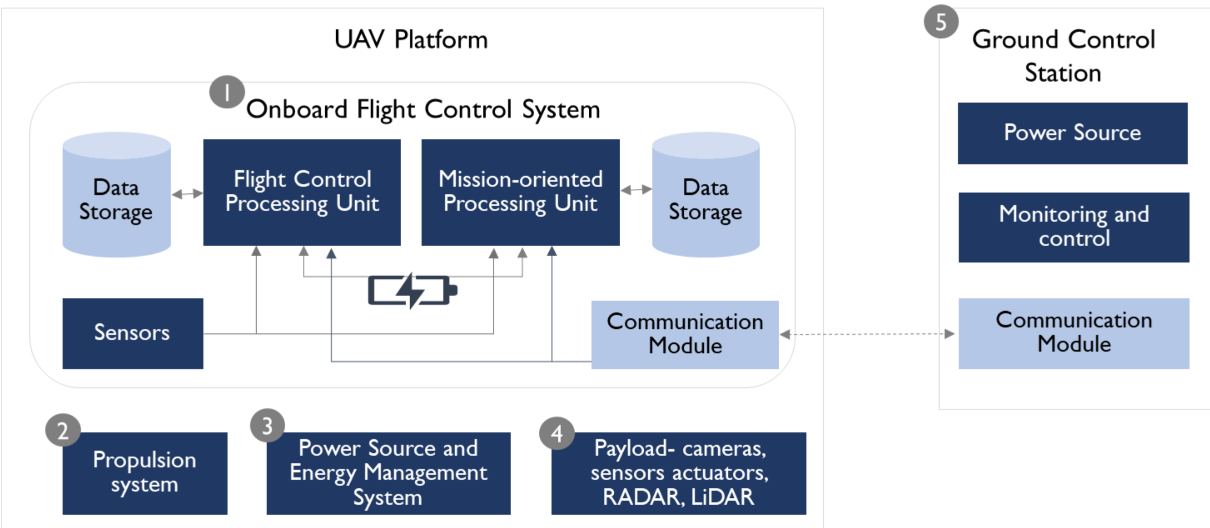
Figure 28: Drone market segmentation



7.1 Drone Hardware

Drones are made up of light composite materials that make them easy to fly and maneuver. A drone has a body or a skeleton, equipment that assists in flight, like rotors, propellors, and a power source. Hardware components of a drone include:
i) an onboard flight control unit, ii) a propulsion system, iii) payload, iv) power system and energy management systems. It interacts with a ground control station, which can be considered a fifth component.

Figure 29: Drone hardware components



Source: (Boukoberine, et al., 2019)

1. **Onboard flight control system** includes necessary hardware such as
    a. units to process data and programs required for flight control and specific applications
    b. data hard drives to temporarily store data for processing and further relaying it back to the ground control station and/or to the cloud storage
    c. sensors to capture the data for flight control
    d. battery for powering processing units
2. **Propulsion system**: it includes the propellor, motor, speed controller, and convertors. The propulsion system forms an integral component of the drone and is responsible for its direction and motion.
3. **Power system and energy management systems** include
    a. power system – a drone can use various power sources and equipment for propulsion such as batteries, combustion engines, hydrogen fuel cells, solar power, drone tethers, laser power beaming; and
    b. energy management system, which splits energy from the power systems to various onboard equipment. The power source can be any or a combination of batteries, combustion engines, hydrogen fuel cells, and solar PV.

4. Payloads

are equipment that carries out application-specific missions and can include actuators, cameras, RADAR, LiDAR, etc. In other words, the payload can also be defined as the weight a drone can carry in the air and has an impact on its flight time. A drone's ability to carry a greater payload offers more flexibility to add additional technology and tools to it. Deliverable payloads (like packages to a consumer) are considered dispensable payloads. Drones used in the power sector for mapping and surveillance, contain non-dispensable payloads such as cameras, sensors, etc.

Key payload equipment used by drone-based applications in the power sector include:

a. ***Visible light (RGB) camera*** – primary equipment to take clear and sharp images for components and parts of power lines and installations.
High Definition (HD) visible light cameras also known as RGB (Red, Green, Blue) image sensors/RGB cameras. Visible light cameras capture the visible light just like the human eye.
b. ***Infrared (IR) camera*** – serves as the thermal detector for overheated fittings or parts due to mechanical or mounting defects
c. ***Thermal camera*** – thermal imaging systems or thermal cameras are passive and only sense the difference of heat to generate the temperature readings for each pixel of the entire thermal image, useful for solar panel hot spot detection and leakages, etc.
Infrared (IR) camera detects the heat generated by a body (due to atomic vibrations) and generates a picture through an IR conversion tube. Thermal camera detects the picture based upon temperature difference between the body and its immediate surroundings to generate a picture.
d. ***Ultraviolet (UV) camera*** – used for examining discharge by detecting corona or arc happening on conductors, insulators, or fittings
e. ***Radio Detection and Ranging (RADAR)*** – high-powered radars can easily pinpoint the location of a person or object. A drone can use radar if its mission is to find a missing object or person, and can be used during emergencies or disaster-related situations
f. ***Light Detection and Ranging (LiDAR)*** – equipment with laser light can measure distance, make high-resolution maps and three-dimensional models for survey and mapping of long-distance transmission corridors
Compared to RADAR, which uses radio waves, LiDAR uses near-infrared laser light. Both technologies have advantages and disadvantages:
    i. Accuracy and resolution: radar has lower accuracy and resolution, while LiDAR is considered more accurate, with the ability to produce high-resolution 3D maps
    ii. Weather operations: radar sensors are not affected by rain, fog, etc., whereas LiDAR is less accurate in bad weather conditions
    iii. Costs: RADAR sensors are cheaper than LiDAR sensors
g. ***Actuators*** – devices that convert electrical signals into physical actions

Figure 30: Illustrative payloads for power sector drone applications

Application(s)	RGB camera	IR/Thermal camera	LiDAR/ RADAR	UV camera
T&D Infrastructure inspection	✓	✓		
Line corridor inspection, vegetation management			✓	
Theft detection	✓	✓		
Corona detection		✓		✓
Solar projects	✓	✓		
Wind projects	✓			
Emergency management, construction and progress monitoring	✓			

5. **Ground Control Hardware:** Ground-based hardware allows UAV operators to communicate with and control a drone and its payloads, either for autonomous operation or by allowing direct control of the UAV. It consists of the following:
    a. ***Processing unit*** – this may be an off-the-shelf laptop with common high-performance processors, or a bespoke system based on an embedded computing platform for monitoring and control.
    b. ***Communication Module*** – this module is responsible for communication between the in-flight drone equipment and the on-ground control system. This module can include receivers, transmitters, GPS module, and cloud storage.
    c. ***Power source*** to power the ground control hardware.

A list of key global and Indian firms active in the drone hardware manufacturing space is presented in Annexure 1.

7.2 Drone Software

The software is mostly described as the brain of the drone and tells it where to go when flying between two points. Flight control, navigation, telecommunication, and decision on what action must be taken with the data received, are all performed by different parts of the software. Data collection and analysis depend on how sophisticated drone software is. For example, drone mapping software captures imagery and/or LiDAR data during missions to create 2D and 3D maps and models. The software also helps drones have situational awareness to make decisions and execute tasks, required for last-mile delivery.

The software component consists of three parts: the system software, a cloud-based drone control platform, and user software. These are detailed below:

1. **System software**
   It consists of the following elements:
    a. ***Embedded software*** acts as a processor, managing hardware, tracking drone telemetry, and partially analyzing data from a variety of drone sensors (GPS, thermal sensors, infrared and LiDAR cameras, ultrasonic and vision sensors, and more).
    b. ***Operating system (OS)*** enables users to manage the firmware. The operating system monitors optic flow and avoids interference while the embedded software searches for the solution and decides the next action.
    c. ***Web and cloud interfaces*** allow access to the OS from remote drone control systems (user applications and cloud control stations) and stream gathered data from embedded software to the cloud or mobile devices.
2. **Cloud-based drone control platform:** This is where data is processed, stored, and analyzed. It also allows a drone to respond autonomously. When it comes to complicated operations like 3D map development, computer vision, and pattern recognition, the cloud component is necessary.
   The cloud-based control platform supports:
    - Streaming of data processor
    - Big data warehouse and data lake
    - Machine learning and data analytics
    - Control module for drones
    - Communication interfaces for the drone
3. **User software:** This includes both the front-end and back-end components of online and mobile applications. They assist users in planning and conducting flights, as well as displaying data

from drones. Communication interfaces with the cloud and the drone are also included in the user software.

A list of key global and Indian firms active in the drone software space is presented in Annexure.

7.3 .Drone Service Providers

Construction, agriculture, utilities, entertainment, and mining have been identified globally as the top sectors for drone use, thanks to the growing demand for applications like inspection, maintenance, monitoring, surveying, surveillance, photography, and more.

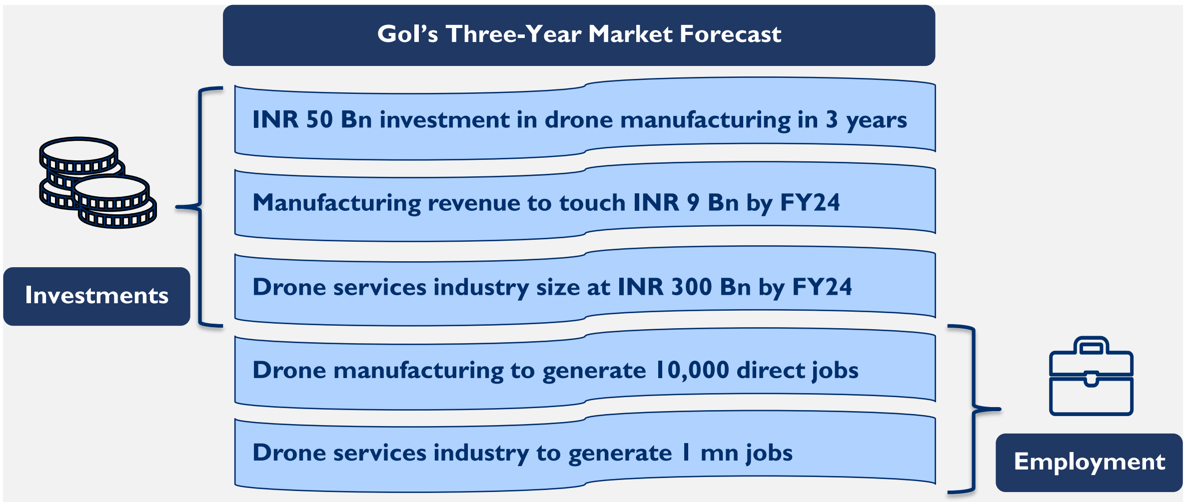
According to Bloomberg NEF research (BloombergNEF (BNEF), 2020), the fastest growing software markets globally for the grid are drones and augmented reality (AR). BNEF estimates the drone and AR software market to be worth $249 million and $119 million, respectively by 2025. Evolution in computer vision software can lead drone flights and inspections to be automated, from the flight path to image analysis.

In line with international trends, in India, the power sector (for both transmission and distribution utilities) is an attractive candidate for drone applications, especially when combined with AI/ML, and offers a host of cost-effective solutions, most of which have been discussed in previous sections.

7.4 India's Drone Landscape

India is the third-largest importer of military-grade drones having 6.8% of total UAV imports. The country's commercial drone market is forecast to grow at a compound annual growth rate of 12.6% from 2020 to 2026 (Vats, 2021). As per the Ministry of Civil Aviation (MoCA) press release on September 24, 2021, the drone manufacturing and service industries are expected to grow to INR 9 billion and INR 300 billion by FY 2024 (Press Information Bureau - PIB, 2021).

Figure 31: Indian drone market projections



Source: (PIB - Ministry of Civil Aviation, 2021)

India's optimism to become the global drone hub by 2030 is underlined by a surge of interest expressed in the sector by established corporates. For example, Reliance Industries Ltd (Das Gupta, 2022), has put in place an aggressive drone business plan that includes expanding the manufacturing capacity, and experimenting with goods delivery to become a key player in the sector by the end of the decade. Similarly, Infoedge India, the parent company of popular websites-- Naukri.com, 99Acres.com, Jeevansathi.com, Shiksha.com, and others -- aims to be a pioneer in drone technology and manufacturing (Equity Master, 2021). Infoedge has invested in Skylark Drones, a startup involved in developing infrastructure for a global drone ecosystem. Food delivery company Zomato is also betting on delivery through drones. In 2020, Zomato partnered with Vodafone Idea to work on beyond the visual line of sight (BVLOS) drones.

These investment announcements come as India continues to take measures to boost the local drone industry. India followed the Drone Rules, 2021 with a Production-Linked Incentive (PLI) scheme that seeks to allocate INR 1.2 Billion for drones and their components, spread over three financial years to boost local manufacturing. At the same time, the Directorate General of Foreign Trade (DGFT) banned imports of drones as Completely-Built-Up (CBU), Semi-Knocked-Down (SKD), or Completely-Knocked-Down (CKD), to increase self-reliance in setting up a local drone manufacturing ecosystem.

According to discussions with industry players, the government's push towards regularizing the industry by implementing Drone Rules, 2021, as well as the import ban of February 2022, are all steps that will enable the sector to grow. The Drone Rules, 2021, are expected to cap cybersecurity breaches and enable uniform standards and procedures, which will deter ad-hoc, fly-by-night operators. Simultaneously, it will strengthen the Indian drone industry by helping serious manufacturing and services to attract more businesses and capital. The number of drone start-ups in India has already increased 34.4 percent since the GoI announced the PLI scheme (Gera, 2022). While in August 2021, India had 157 drone start-ups, the number of drone start-ups as of February 8, 2022, is 211. Indian dronepreneurs hope the PLI amount and duration will further expand and will continue to get additional government support.

The February 2022 ban on shipments by the Indian government, is an initiative to cap the import of cheap and substandard drones. Discussions with Indian industry players revealed that this will raise drone costs by 20 to 30 percent soon as sourcing for components will shift to places like Germany and Japan. However, higher demand from corporates and public schemes may soon generate enough volumes to balance this cost increase.

The Indian drone sector is evolving, and many start-ups have entered the arena over the last few years, focusing primarily on the power sector. Some of the key firms active in the Indian power sector include IG Drones, Garuda UAV, VIDRONA, and IdeaForge, as shown in Table 22 below.

Table 22: Key drone service providers for the power sector

Firm	Key Applications	Major Clients
Key drone service providers active in India		
Aarav Unmanned Systems (AUS), Bengaluru	Surveying and mapping, power distribution lines, wind farms	Adani, JSW, Vedanta
Airpix, Mumbai	Surveying and mapping, wind turbine blade inspection	Suzlon, Indian Railways, Kalptaru, Enrich, Reliance Energy, WAPCOS
Asteria Aerospace, Bengaluru	Inspection and maintenance, site planning, solar farms, logistics and quality control	Reliance Industries, armed forces
Garuda UAV, Noida	T&D, solar plant, and thermal plant inspection	TPDDL, Renew Power, Susten, NTPC, GE Power, Kalptaru
IdeaForge, Mumbai	Transmission, solar, wind	NTPC, armed forces, railways, agriculture sector

Firm	Key Applications	Major Clients
IG Drones, New Delhi	Power line monitoring, solar plant inspection	PowerGrid, Reliance Power, Adani, Sekura, IndiGrid
Vyomik Innovations, Hyderabad	Transmission line surveys, wind plant surveys, solar PV surveys	PowerGrid, NRI Power and Infra
VIDRONA, U.K.	Distribution and transmission line inspection, windmills and solar farms inspection	Scottish Power, Northern PowerGrid, Northern Ireland Electricity, BSES, Tata Power, Adani
Key international drone service providers		
Cyberhawk, U.S.	Power generation, power grid, oil, and gas	BP, Total, SSEN Transmission, Network Rail, Kinsale energy
DelAir, France	T&D infrastructures, security, and defense, geospatial, agriculture and forestry	Enedis, RTE, Trimble, BASF
Percepto, U.S.	Inspection rounds, modeling and measurement, construction monitoring, security, emergency response, and remote operations	Enel, Florida Power and Light, ICL Dead Sea, Verizon, Koch, Johnson Controls
Precision Hawk, U.S.	Distribution utilities, transmission utilities, solar farms, oil and gas, and agriculture	Munich Re, US Dept of Defense, BASF, NASA
Sterblue, U.S.	Distribution grid, transmission grid, wind turbine and cooling tower	AEP renewables, Pronto Solutions, EDP Renewables, Enedis, ESB Group, Innogy

7.5 Capacity and Training for Drone Operations

India foresees the drone services industry (operations, logistics, data processing, traffic management, etc.) on a far bigger scale than manufacturing. As per government estimates, it is expected to grow to over INR 300 billion in the next three years and will generate over five lakh jobs in three years (Ministry of Civil Aviation - PIB, 2021).

This naturally calls for large-scale skill and capacity development, as ‘Make in India’ and `Skill India’ go hand-in-hand. The drone industry will need operators, technicians, and engineers with the right technical skills, combined with the applicable soft skills required for the industry. NIT Andhra Pradesh, for instance, is set to become one of the first engineering institutes in India to offer a minor degree in Drone Studies in the coming months. Some of the key drone-related job roles could be Drone Pilots, Pilot Trainers, Pilot Certifiers, Drone software developers, Drone Assembling Experts, and Drone Technical Support Staff.

The DGCA has authorized 23 Remote Pilot Training Organizations (RPTOs), the syllabus, training, and procedures manual, to assess whether the procedures developed by the organization are in line with the existing requirements.

Given the expanding drone industry and its requirements, there is ample scope for more training institutes to come up. This can happen through state-led initiatives, e.g., Haryana (Nazir, 2022) will soon get an institute to train drone pilots under the aegis of Drone Imaging and Information Service of Haryana Ltd (Driishya). The institute is expected to cater to various training needs of personnel of Driishya and other organizations.

Given the expanding drone applications in the country, the private sector has a big role to play in skill development and has already started taking initiatives to build the workforce for these services.

Recently the Indian Institute of Technology (IIT) at Roorkee, Garuda Aerospace, and AGROB, both leading start-ups, signed a long-term partnership agreement (India Today, 2022) to jointly address the growing demand for indigenous drone pilots in the rapidly developing Indian ecosystem.

Another example is IG Drones instituting a Centre of Excellence (CoE) that aims to educate over 1 million students on the latest drone technologies. Over 2020 and 2021, the institute had 450,000 pass-outs. The project collaborates with the National Development Skills Council (NSDC) and various government technical institutes and polytechnics across the nation to undertake training. The institute has designed a module to train students specifically for the power sector's requirements, as industry-specific courses are a lacuna that is yet to be addressed on a wider scale. Such modules need standardization and validation by the industry to enable the absorption of students into jobs.

IG Drones' CoE currently offers 3-month flying courses and 5-month courses covering additional aspects, priced at INR 65 per hour.

In a positive move, the Union Minister for Civil Aviation announced in May 2022 that the fees for drone pilot training courses will significantly decrease over the next 3-4 months (Bhatnagar, 2022), as more institutes get the necessary certification from the DGCA. Currently, the fee ranges between INR 30,000 – INR 100,000 depending on the course. He also said that drone schools will soon be free to grant certification, instead of DGCA itself.

Key Considerations for India

8 KEY CONSIDERATIONS FOR INDIA

Remotely configured, controlled, monitored, and unmanned aerial devices – drones – could appear as the perfect eye in the sky that could replace humans in jobs requiring aerial inspection of power systems, network surveillance and maintenance, fault detection, and possibly even fault prevention. However, drone flights and operations come with challenges that could vary from operational issues to safety hazards and data security. Some of the challenges can be identified as under:

8.1 Operational Issues

Once a drone has successfully taken flight, keeping it moving, maintaining battery backup, obstacle detection, and navigation control in case communication with the ground control center is lost are some of the major challenges faced.

While on one hand utilities feel that it is challenging to operate drones in densely populated urban areas, on the other hand, the (Drone Service Providers (DSPs) are apprehensive about timely payments from these customers in general. For any utility complete GIS mapping of assets using drones alone is not possible because of restrictions arising out of underground power lines, no flying zones for drones, etc., Therefore, a unified system must be developed to process GIS data that is captured either by drones and/or manually. Acceptability of this technology for the power sector is going to be equally crucial.

8.2 Safety Hazards

Studies conducted globally to encourage penetration of drones have indicated that they cannot and should not fly in all types of weather. Air temperature, wind speed, precipitation, and other atmospheric phenomena are known to adversely affect drone endurance, control, aerodynamics, airframe integrity, line-of-sight visibility, airspace monitoring, and sensors for navigation and collision avoidance (Gao, et al., 2021).

Studies have also indicated that drone weatherproofing is possible, which can increase their flyability, but it does not guarantee safe operations. Weather conditions can also seriously impact drone application for wind site inspections (The legal Drone, n.d.).

Increased use of UAVs in urban areas can increase the risks of accidents and lead to incidents resulting in the loss of life or property. Any failure or crash of drones due to reasons of human error, loss of signal between drone and pilot, as well as technical errors can lead to incidents that are dangerous not only for the infrastructure but also for human and animal life. It is considered inevitable that UAVs and manned aircraft may soon share the same airspace, which will further complicate and magnify the problem of severe collisions (Radišić, et al., 2018). Avoiding such aerial accidents could become one of the limiting factors for the further development of unmanned aviation systems.

8.3 Privacy Concerns

A drone flying overhead in a particular area to reach a distant transmission line also has privacy issues related to it. A notorious intervention on the images captured by a drone and video-taping can have damaging consequences on the lives and privacy of individuals. Restricting access to image capturing and securing an individual's privacy is also a challenge to be addressed as various sectors open up for the drone industry.

8.4 Data Security

Globally it is common practice that drones deployed for commercial purposes are relatively light and small, unlike drones deployed for military or defense purposes. The remotely controlled communications usually rely on encrypted codes, which being static in nature, are prone to security issues and easy hijacking (Swidch, 2021). Therefore in infrastructure-intensive sectors, data privacy and security issues with drones could have snowballing consequences. An example is that of a drone trying to interrupt a grid in Pennsylvania, U.S., in 2021 and was recovered next to a substation (ABC News, 2020). Federal officials issued a law enforcement bulletin to raise awareness about drones as a threat to critical infrastructure. Any such attack is potentially a national security threat.

As per (Sultan, 2022) the most common attacks are:

- Identity or password theft to access a device, leading to authentication breach
- The Man in the Middle (MITM) method where an attacker has access to communication between two parties and can alter and get confidential data without the user's knowledge
- Denial of Service (DOS) is an attack that prevents contact with the UAV
- GPS jamming that conflicts with signals that lead to drone malfunction

Regulatory and Policy Regime

9 REGULATORY AND POLICY REGIME

Following the COVID-19 outbreak in March 2020, many states in India went under complete lockdown, which restricted the movement of people and transportation. The power sector witnessed challenges in conducting inspections, fault detection, and providing time-bound resolution, particularly in the distribution and transmission networks. The same can be ascertained in the light of Suo-moto Orders (Delhi Electricity Regulatory Commission - DERC, 2022), for suspension of Standards of Performance of Utilities, passed by State Electricity Regulatory Commissions (SERCs) across the country. Under such circumstances, the use of drones in network monitoring and fault identification would have played a crucial role in averting prolonged system inefficiencies and maintaining the safety and reliability of the power system.

In India, UAVs were originally developed for the military and aerospace industries. The Directorate General of Civil Aviation (DGCA) governs the use of all aerial vehicles (manned or automated). Back in the 1990s (Hussain, 2022), the Indian Army acquired unmanned aerial vehicles or UAVs from Israel, and the Indian Air Force and Navy followed suit. India first used military drones during the 1999 Kargil war against Pakistan for photo reconnaissance along the Line of Control (LOC).

India's temporary blanket ban on drones in 2014 (Kislay, 2021), with lawmakers grappling with the questions about safety and ownership of airspace and trespassing of privacy, was a major speed breaker in the process of developing drones and drone-based solutions in India.

The office of the Director-General of Civil Aviation (DGCA) issued the first notification on drones in India on October 7, 2014. Two factors that governed drone usage were – the weight that defines its size and its ability to fly unmanned outside the visual line of sight. The first set of guidelines only allowed Mini and Macro drones with visual line of sight (VLOS) to operate.

The 2017 regulations stipulated that "all UAVs, irrespective of weight category, could fly while maintaining Visual Line of Sight (VLOS)." Since the guidelines had gaps, issues like legal liability and import controls, the UAVs compulsorily needed to get a 'Unique Identification Number' (UIN) for security clearance from the Ministry of Home Affairs before becoming operational. The Draft 2018 DGCA Guidelines assigned the legal responsibility of UAVs to their respective operators. As the discourse on drones has developed, the guidelines and protocols have also matured over time.

In India, drone operation for commercial use across sectors has been restricted and largely unregulated until a long time. The National Drone Policy legalized drone-use in 2018, for purposes beyond national defense and security activities. On August 25, 2021, the Ministry of Civil Aviation (MoCA) notified the Drone Rules, 2021 (hereafter referred to as the Rules) which superseded the Unmanned Aircraft System Rules, 2021. The following sub-sections provide an overview of key policy and regulatory provisions for operating drones.

9.1 Drone Rules, 2021

The new rules are viewed as industry and user-friendly, as they simplify many restrictive provisions and remove cumbersome approvals needed to fly a drone. Key provisions of the Drone Rules 2021 are –

Table 23: Key provisions under Drone Rules, 2021 (Ministry of Civil Aviation, 2021)

<table>
<tr><th>Provision</th><th>Particulars</th></tr>
<tr><td>Applicability</td><td>All drones registered or being operated in India with a maximum weight of up to 500kg</td></tr>
<tr><td>Definitions</td><td>Drones - means an Unmanned Aircraft System
Unmanned Aircraft Systems (UAS) - means an aircraft that can operate autonomously or can be operated remotely without a pilot on board</td></tr>
<tr><td>Categorization</td><td>Aeroplane UAS – fixed-wing UAS
Rotorcraft UAS – power-driven rotors on the vertical axis for take-off and flight
Hybrid UAS – uses rotors for vertical take-off and lift and non-rotating airfoil for horizontal flight; can have both battery and combustion engine</td></tr>
<tr><td>Classification</td><td>Nano UAS - <0.25kg
Micro UAS - 0.25-2kg
Small UAS - 2-25kg
Medium UAS - 25-150kg
Large UAS - >150kg</td></tr>
<tr><td>Airspace maps</td><td><table>
<tr><th>Particular</th><th>Green Zone</th><th>Yellow Zone</th><th>Red Zone</th></tr>
<tr><td>Permission</td><td>No permission is required</td><td>Permission from Air Traffic Control Authority is required</td><td>Permission from the central government is required</td></tr>
<tr><td>Vertical range: 8-12km of lateral distance from airport periphery</td><td>0-60m</td><td>>60m</td><td>As per permission</td></tr>
<tr><td>Vertical range: beyond 12km</td><td>0-120m</td><td>>120m</td><td>As per permission</td></tr>
</table></td></tr>
<tr><td>Permissions</td><td>Type certificate for the drone model
Unique Identification Number (UIN) for each drone through registration on DigitalSky
Unmanned Aircraft Operator Permit (UAOP) from DGCA via an application on DigitalSky
Pilots flying drones need to obtain a drone pilot license (except for non-commercial nano or micro-UAS pilots)</td></tr>
</table>

The following regulatory provisions are highlighted in the rules.

- The rules specify that no UAS can operate in India unless it conforms to a type certificate or is exempted from such certification. A model remotely piloted aircraft system and a nano unmanned aircraft system are exempted from obtaining a type certificate.
- The rules also entail procedures for the issuance of type certificates.
- Certification standards are to be specified by Central Government (CG) based on recommendations of the Quality Council of India.
- The rules highlight that Central Government shall notify mandatory safety features to be installed in a UAS.
- “DigitalSky” is to be developed as a user-friendly, single-window online system for all approvals and permissions.
- Every UAS needs to be mandatorily registered on the DigitalSky platform and shall be allotted a unique identification number unless exempted to do so; the nano category is exempted.
- Nano category does not also require Unmanned Aircraft Operator Permit (UAOP).
- Penalty to any person, subject to his/her failure to comply with the provisions of the Rules, is limited to up to Rs. 1 lakh.

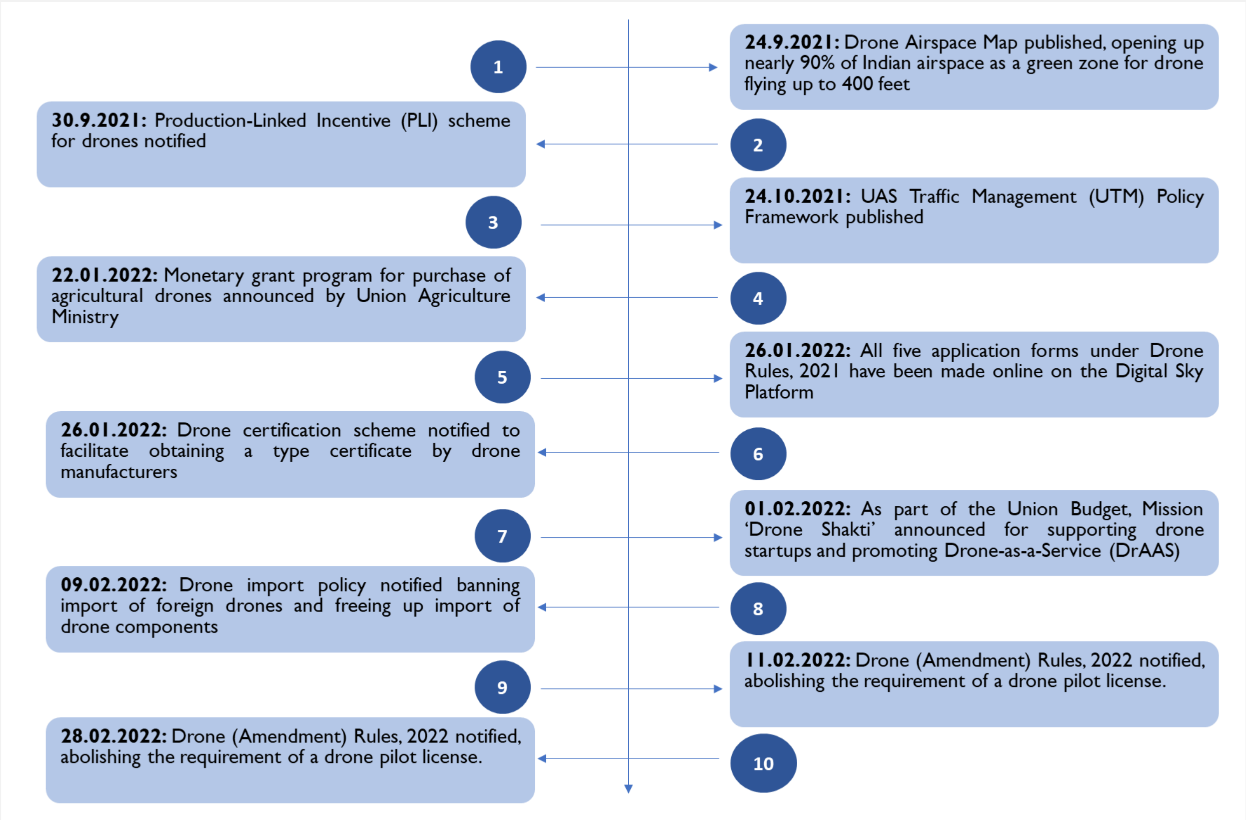
- The forms to be filled in in the new rules are fewer in number (five), linked to obtaining a type certificate, and applications for registration, de-registration, transfer of a UAS, remote pilot certification, and establishment of a remote pilot training organization.
- For training of remote pilots operating the UAS, the Rules have a separate section specifying the training needs and mandate to establish a training organization; for issuing a remote pilot certificate to any person the Directorate General of Civil Aviation (DGCA) has to specify the training needs, syllabus, test qualifications, etc. on the DigitalSky platform.

The Rules have defined roles and responsibilities under many regulatory/statutory/quasi-judicial bodies as highlighted above. Effective operations by these bodies would also play a key role in upscaling drone technology use cases in the country.

Policy Thrust

With the government's vision of providing impetus to the Drone Industry, a series of policy and facilitative measures have followed the Drone Rules –

Figure 32 Policy measures to facilitate drone operations



Obtaining a 'Remote Pilot' License

The Drone Rules mandate that the persons authorized to operate the UAS remotely shall obtain a pilot license under the Rules. The Director General of Civil Aviation (DGCA) will be responsible for issuing the remote pilot license.

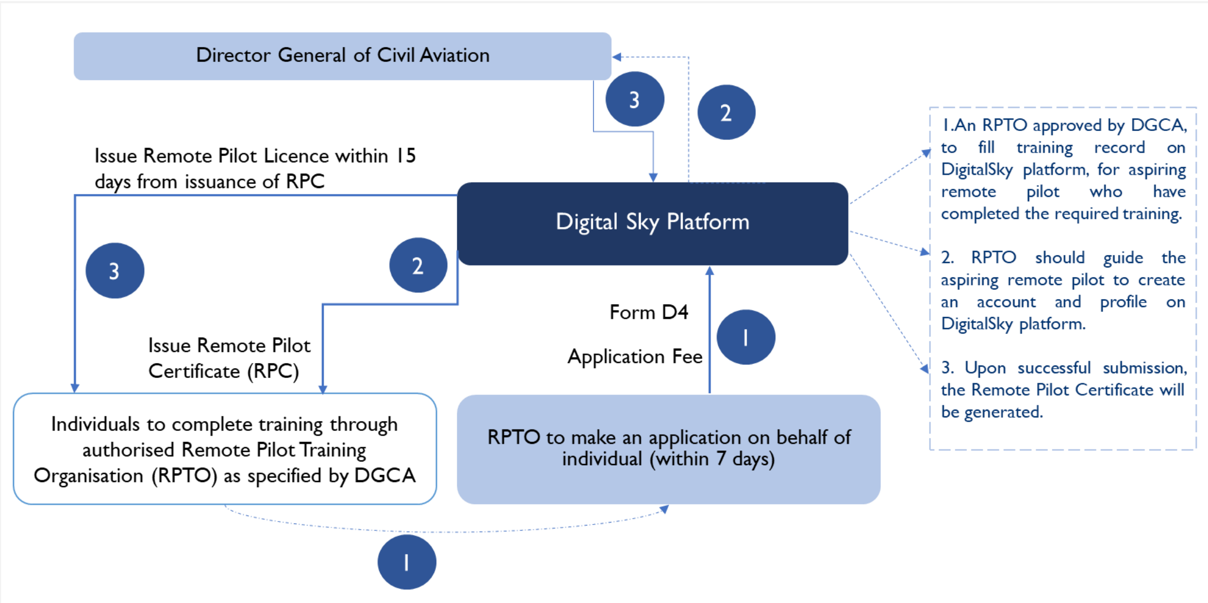
Any person meeting the following requirements shall be eligible for a 'remote pilot' license -

- **Age:** should be 18 years of age and above and not more than 65 years of age
- **Education:** passed class tenth examination or its equivalent from a recognized board

- **Professional Training:** completed such training as may be specified by the Director-General, from any remote pilot training organization authorized as a training organization by the DGCA

An individual, to obtain a remote pilot license should specify the category, sub-category, or class of a UAS, and combinations thereof, for which the person will be willing to obtain the pilot license and shall complete the training specified by the DG, through the authorized remote pilot training organization as per Rule 38 & 39 of the Drone Rules. The process for issuance of a 'remote pilot' license under the Rules, is depicted below –

Figure 33: Process for issuance of 'remote pilot' license



Source: Drone Rules, 2021 (Ministry of Civil Aviation, 2021)

A remote pilot license shall be valid only if it is enlisted on the DigitalSky platform and shall remain valid for a maximum period of ten years. No remote pilot license shall be required to operate a nano-unmanned or a micro-unmanned aircraft system for non-commercial purposes.

9.2 Airspace Maps for Drone Operation

The drone airspace map is an interactive map of India that demarcates the yellow and red zones across the country. The drone airspace map is freely available on the DigitalSky platform and can be accessed by all.

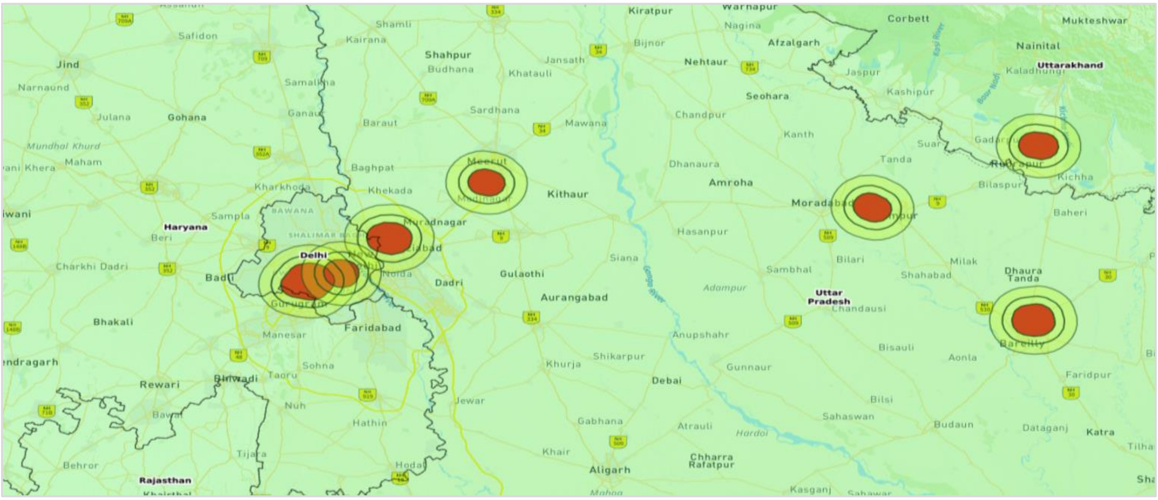
The DGCA has released a color-coded dynamic and interactive map within the DigitalSky platform indicating the various zones where drones can operate.

- **Green zone** is the airspace up to 400ft that has not been designated as a red or yellow zone; and up to 200ft above the area located between 8-12km from the perimeter of an operational airport.
  - In green zones, no permission is required to operate drones with an all-up weight of up to 500kg.
- **Yellow zone** is the airspace above 400ft in a designated green zone; above 200ft in the area located between 8-12km from the perimeter of an operational airport and above ground in the area located between 5-8km from the perimeter of an operational airport.

- Drone operation in the yellow zone requires permission from the concerned air traffic control authority – Airport Authority of India, Indian Air Force, Navy, Hindustan Aeronautics Limited, or any other.
    - **Yellow zone** has been reduced from 45km earlier, to 12km from the airport perimeter.
- **Red zone** is the 'no-drone zone' within which drones can be operated only after permission from the Central Government.

An illustrative image of boundaries reflected in the airspace map is presented below –

Figure 34: Illustrative DigitalSky airspace map



Source: DigitalSky Platform (DigitalSky DGCA, n.d.)

Note: Red and yellow zones are shown in concentric circles, and anything outside the scope of these circles is the green zone

From time to time, the airspace map may be modified by authorized entities. Anyone planning to operate a drone should mandatorily check the latest airspace map for any changes in zone boundaries.

9.3 National UAS Traffic Management Policy (UTM Policy)

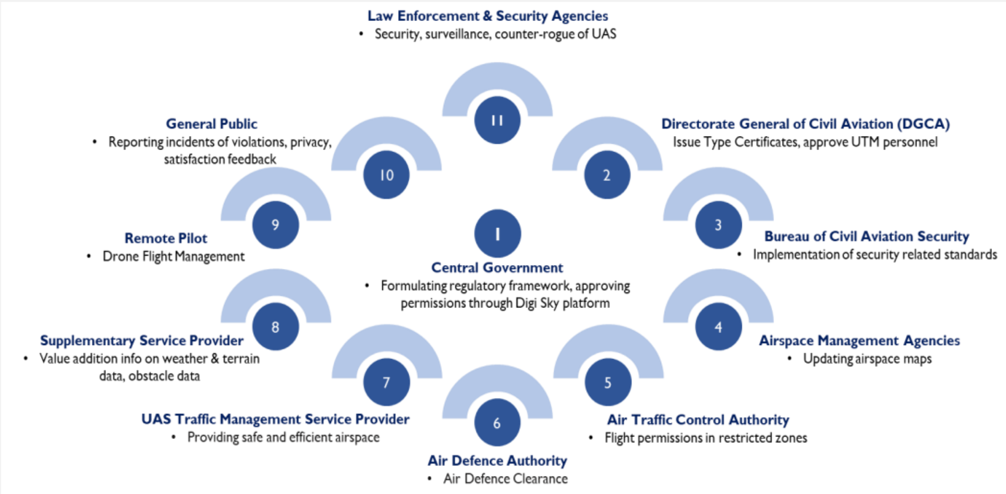
The current Air Traffic Management (ATM) systems are not equipped to handle the traffic from unmanned aircraft. Integrating the operation of manned and unmanned aircraft across the Indian airspace, while ensuring safety is a critical requirement enabled by a combination of standards, procedures, technology, and real-time data exchange.

Accordingly, the National UAS Traffic Management (UTM) Policy (Ministry of Civil Aviation, 2021) has been formulated under the overarching framework of the Drone Rules, 2021. The UTM Policy regulates the architecture and mechanism of traffic management of drones in 'very low level' (VLL) airspace i.e., up to 1000 feet above the ground level (UTM airspace).

UTM Stakeholders

The Policy envisions active collaboration between stakeholders connected through data exchange. It has laid down 11 key stakeholders including the public, law enforcement agencies, and air defense authority as illustrated in Figure 35.

Figure 35: UTM policy- key stakeholders



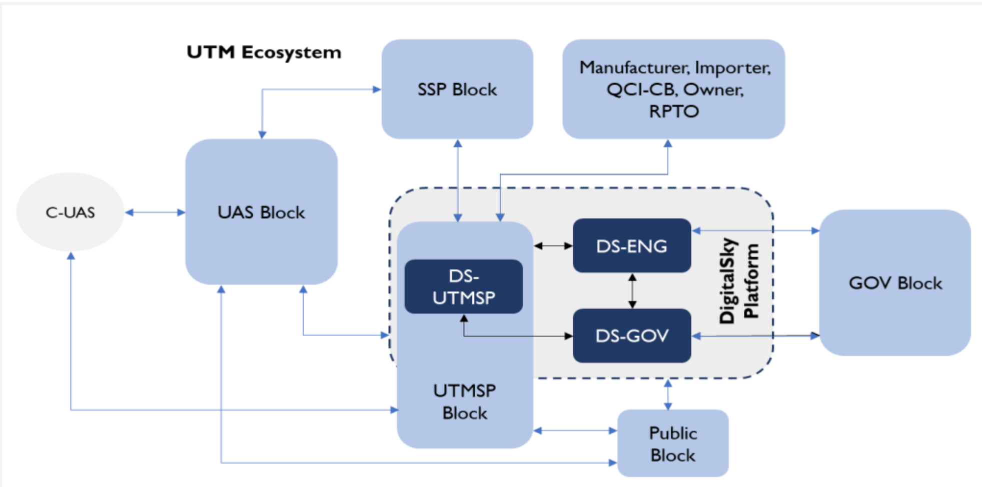
Source: National Unmanned Aircraft System Traffic Management (UTM) Policy Framework (Ministry of Civil Aviation, 2021)

The UTM policy showcases the building blocks of the UTM architecture which primarily are the DigitalSky platform, UTM service providers, UAS supplementary service providers, unmanned aircraft systems, remote pilots, government stakeholders, and the general public. The policy enlists each component and explains the role of each in creating an ecosystem for UAS traffic management.

UTM Architecture

The UTM ecosystem, as illustrated in Figure 36, is envisioned as a collaborative extension of the current ATM services and applies to any unmanned aircraft in the airspaces where such ATM services currently either do not exist or are not adequate to handle the expected volume of unmanned aircraft traffic.

Figure 36: UTM ecosystem architecture



Source: National Unmanned Aircraft System Traffic Management (UTM) Policy Framework (Ministry of Civil Aviation, 2021)

The UTM architecture is primarily divided into the following blocks:

- **DigitalSky platform block** – creates a centralized digital regulatory ecosystem and enables the primary stakeholders of the UTM ecosystem to collaborate in real-time mode. It consists of three components:

- **DigitalSky Engine (DS- ENG)** – responsible for managing different databases, implementing business rules, and integrating with various third-party services and platforms.
- **DigitalSky Government (DS- GOV)** – acts as the primary user interface for departments and agencies of both central and state governments to interact with the UTM ecosystem and perform various administrative functions.
- **DigitalSky UTM Service Provider (DG UTMSP)** – shall operate pan-India and provide services to government and private stakeholders, for the safe conduct of unmanned aircraft operations.

- **UTM service providers block** – acts as real-time or a near real-time interface between key stakeholders of the UTM ecosystem. It allows unmanned aircraft owners and remote pilots to register, seek permissions, and communicate with other stakeholders as required.
- **UAS supplementary service providers block** – provides data related to weather, terrain, obstacles, navigation, airspace surveillance, etc., to enhance the safety of unmanned aircraft operations.
- **UAS block** – represents UAS and remote pilots.
- **Government block (GOV Block)** – represents the government stakeholders responsible for creating business rules and safety standards, issuing licenses, permissions, monitoring traffic, etc.
- **Public block** – makes data available to the general public via UTM Service Providers (UTMSPs) related to unmanned aircraft operations; the general public may also report violations to UTMSPs.
- **Counter UAS (C-UAS):** to protect sensitive areas by detecting and identifying unmanned aircraft systems operating in such areas.

Each component provides a specific user interface and Application Programming Interface (APIs) for stakeholders to interact with the UTM ecosystem and perform their primary functions while ensuring safety and security related to UAS operations in India.

9.4 Production Linked Incentive Scheme (PLI)

The scheme, notified on September 30, 2021, provides an incentive of Rs. 120 Crore to drone manufacturers and component manufacturers, spread over three years. The following table provides key provisions under the PLI scheme.

Table 24: Key provision under PLI Scheme

Key Provisions	
Eligibility	• All drone manufacturers in India • Manufacturers of the following drone components (list subject to revision by CG from time to time) a) Airframe, propulsion systems (engine and electric), power systems, batteries, associated components, and launch and recovery systems b) Inertial Measurement Unit, Inertial Navigation System, flight control module, ground control station and associated components c) Communications systems (radio frequency, transponders, satellite-based etc.) d) Cameras, sensors, spraying systems, related payload etc. e) 'Detect and Avoid' system, emergency recovery system, trackers, and other components critical for safety and security.
Minimum Annual Sales Turnover	• Indian Micro Small & Medium Enterprises & Startups (Rs. 2 Crore for drone, Rs. 50 lakhs for the component) • Indian non - MSME (Rs. 4 Crore for drone, Rs. 1 Crore for the component)

Source: PLI Scheme (Ministry of Civil Aviation - PIB, 2021)

Under the scheme –

- The Government will provide an incentive amounting to Rs. 120 Cr spread over three financial years. The PLI rate is 20% of the value addition, one of the highest among PLI schemes.
- The value addition will be calculated as the annual sales revenue from drones and drone components (net of GST) minus the purchase cost (net of GST) of the drones and their components. The PLI rate has been kept constant at 20% for all three years, an exception for promoting the manufacturing industry for drones.
- Another exception is the minimum value addition norm kept at 40% of net sales for drones and drone components instead of 50%.
- Coverage of the scheme includes developers of drone-related software also.
- PLI for a manufacturer shall be capped at 25% of the total annual outlay. If a manufacturer fails to meet the threshold for the eligible value addition for a particular financial year, he will be allowed to claim the lost incentive in the subsequent year if he makes up for the shortfall in the next year. The Government invited applications from the drone industry up to March 31, 2022.

9.5 Certification Scheme for Unmanned Aircraft Systems

The Certification Scheme for Unmanned Aircraft Systems was notified on January 26, 2022. The scheme covers certification of UAS for the following scenarios:

i. Flying in visual line of sight
ii. Flying in day and night
iii. Flying below 400ft

The scheme aims to provide guidelines and evaluation methods to agencies for issuing the type certificate to drones under the Rules. The Certification scheme has two parts: i) the governing structure, roles & responsibilities of stakeholders; and ii) certification criteria.

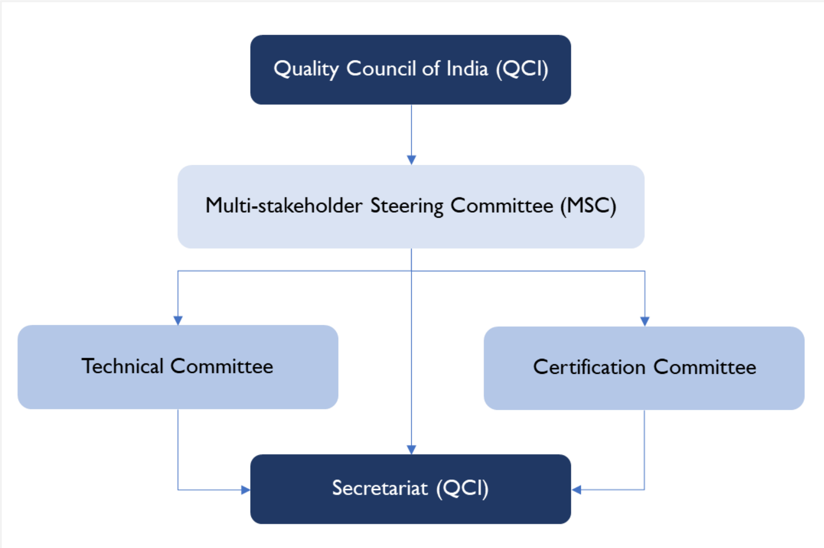
Governing Structure

The governing structure of the Certification Scheme shall have a Multi-Stakeholder Steering Committee (MSC) at the apex level supported by a Technical and Certification Committee, each with its secretariat in the Quality Council of India. The roles and responsibilities of key stakeholders are listed below:

- **Ministry of Civil Aviation (MoCA)** is the nodal ministry responsible for preparing the rules and regulations for operating Unmanned Aircraft Systems (UAS) in India.
- **Director General for Civil Aviation (DGCA)** is the authority for issuing the Type-Certificate of the UAS, as it is the principal regulator in the aviation sector.
- **Quality Council of India (QCI)** is the scheme owner and owns the Certification Mark(s). QCI is responsible for establishing the **Multi-Stakeholder Steering Committee (MSC)** and for the overall management of the Scheme. The QCI will provide the **Secretariat services** to MSC for the administration of the Scheme. QCI is responsible for setting up the Technical and Certification Committees and providing secretariat services.
- The **National Accreditation Board for Certification Bodies (NABCB)** shall be responsible for accrediting certification bodies that wish to participate in the Scheme to appropriate international standards.
- The **National Accreditation Board for Testing and Calibration Laboratories (NABL),** a constituent board of the QCI, is responsible for accrediting testing and calibration laboratories to appropriate international standards to support the Scheme.

The governing structure of the Certification scheme is as below:

Figure 37: Governing structure of certification scheme for UAS



Source: Certification Scheme for Unmanned Aircraft Systems (Ministry of Civil Aviation, 2022)

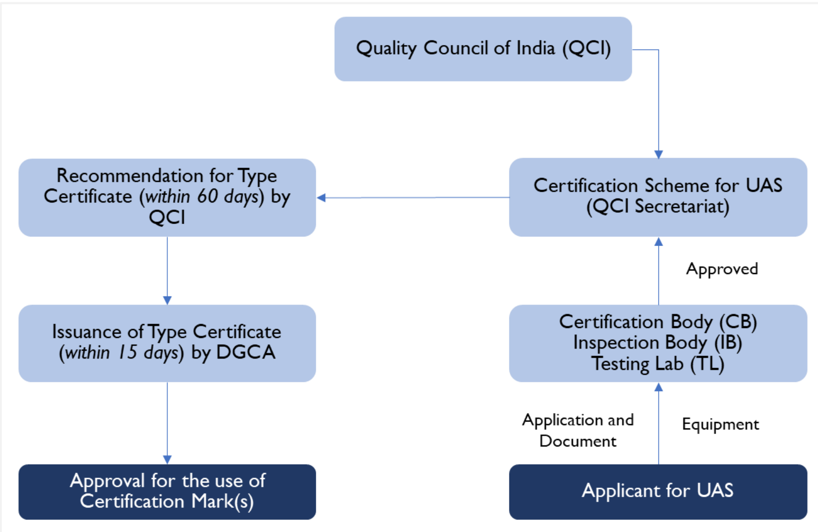
Certification Criteria

Certification criteria under the scheme apply to UAS manufactured by indigenous manufacturers and importers of UAS in India. The indigenous manufacturers, importers, and assemblers of UAS are termed 'Manufacturers' under the UAS Certification Scheme. According to the Drone Rules, type certification is not required for Remotely Piloted Aircraft and Nano Unmanned Aircraft Systems. All other UAS requires type certification before operation.

The scheme provides detailed evaluation criteria on various general requirements including performance, construction, material, communication systems, secure flight mode, tracking mechanism, instruments & equipment, and testing parameters, to be evaluated and verified for issuance of a certificate.

The UAS test certification process is in the figure below.

Figure 38: Process for UAS test certification



Source: Certification Scheme for Unmanned Aircraft Systems (Ministry of Civil Aviation, 2022)

Way Forward

10 WAY FORWARD

Power sector utilities in many developed countries such as Australia, Canada, China, Spain, the U.S., and the U.K, have identified and tapped the potential of drone technologies to improve their operational efficiency. Multiple use-cases of the drone applications deployed globally demonstrate significant cost savings compared to the business-as-usual scenarios. Further, drone operations provide non-tangible benefits such as better job quality, safer work environment, reduced downtime, and enhanced reliability.

However, use of drone technology in power sector in India is still limited. Given the potential of drone applications, a cohesive and collaborative ecosystem needs to be developed by – supporting regulatory and policy framework, encouraging adoption of advanced technologies, capacity building and training, and establishing techno-commercial feasibility of drone applications.

10.1 Enabling Regulatory and Policy Framework

The regulatory and policy framework around drones in India encapsulates the registration and unique identification of every drone (except the exemptions). This is a especially important step in ensuring safety is by correct identification in case of an incident. Formulation of policy and regulatory framework is just the beginning of reforms. The statutory/quasi-judicial/regulatory bodies will have to play a key role in the faster adoption of drone applications across sectors, including the power sector.

Key considerations that can drive faster adoption include:

- Developing a governance structure enabling better coordination, active role-playing, deployment of proof of concepts (POCs), facilitating permits and clearances, creating awareness, etc., will be the key to moving forward successfully.
- Regarding data security issues, support to the Central Electricity Authority (CEA) and other regulatory bodies, for the development of regulations, standards, and codes of practice, for enforcing a data protection regime will be critical.
- Manufacturers would also have to specify safe-operating limits or warnings after conducting weather-resistant tests on the drones under different atmospheric phenomena. Developing standard operating procedures (SOPs) would be the key here.

10.2 Encouraging Adoption of Advanced Technologies

Digital technologies such as drones have become an ideal candidate for powerline health inspection, substation inspection, consumer mapping, and handling power theft menace.

Stakeholder consultations at the time of this whitepaper development revealed that multiple drone applications are being developed by combining advanced payloads, sensors and AI/ML algorithms to suit the requirements of the Indian power sector utilities. Creation of testbeds can foster the development and accelerate adoption of such applications. SAREP is working with Madhya Pradesh Discom to implement a pilot project on "Distribution Asset Health Monitoring using Drone

Applications" . The outcome of this study will disseminated with other distribution utilites to encourgae faster adoption of drones technology.

Going forward, Hydrogen-powered fuel cells could be the way forward for powering drones, and the development of internal hardware with enhanced functionalities by encouraging market forces to innovate would help mitigate operational issues related to powering and remote control of drones.

10.3 Capacity-building and Training

Drone technologies have the potential to transform the 'labor-intensive' jobs in into 'technical jobs'. However, the adoption of drone applications for the power sector would also create a requirement for skilled workforce to operate, develop and maintain drone applications. Therefore, large-scale capacity building programs and training through central institutes such as NPTI, CPRI, IIT's and state level training centers would be required to: skilling, upskilling of the existing workforce in the power sector; and skilling of the new workforce.

10.4 Establishing Techno-Commercial Feasibility

This paper reviews the regulatory framework, use cases of drones in transmission, distribution, and clean energy projects, the existing landscape, and the benefits drone program can offer to utilities. Future-focused utilities that are leading renewable transition and are keen to build internal capabilities should pilot drone applications and make them a part of their digital development strategy.

With the recent thrust by the Government of India under Revamped Distribution Sector Scheme (RDSS), for distribution utilities, piloting drone applications can become a good starting point to bring artificial intelligence for making informed decisions on loss reduction, predictive maintainence, consumer indexing and asset management. Demonstrating and promoting the broad use of such technologies can address certain utility-specific problems and contribute a great deal towards enhancing the operational efficiencies of utilities.

ABOUT SAREP

The South Asia Regional Energy Partnership (SAREP) serves as a flagship program to advance objectives of the U.S. Government's Clean Asia Enhancing Development and Growth through Energy (Clean EDGE) initiative. SAREP improves access to affordable, secure, reliable, and sustainable energy in six countries – Bangladesh, Bhutan, India, Maldives, Nepal, and Sri Lanka – to strengthen systems and processes, in line with the economic and energy-security priorities of these countries.

This program furthers the U.S. Government's Indo-Pacific Vision of facilitating collaboration among the six countries, to operate and accelerate the transition to clean energy, mitigate climate change, and promote energy security, economic development, self-reliance, livelihood, health, and productivity.

SAREP's activities and outcomes also support and contribute to the Strategic Clean Energy Partnership (SCEP) and the Climate Action and Finance Mobilization Dialogue (CAFMD) under the recently established U.S.-India Climate and Clean Energy Agenda 2030 Partnership. Through this collaboration, India, and the U.S. aim to demonstrate swift climate action that is inclusive, resilient, and based on national and regional priorities. Countries in the region will also benefit from each other's experiences through this collaborative program by sharing of the learnings, best practices, and lessons.

By 2026, upon the conclusion of its activities, SAREP aims to leverage US$7 billion in private investment in power infrastructure, increase clean energy capacity by 5,000 megawatts (MW), save 435-gigawatt hours (GWh) through energy efficiency, and facilitate 4 terawatt-hours-worth (TWh) of cross-border trade.

SAREP is working through four technical objectives and three cross cutting themes. The program is also providing grants to demonstrate innovative pilots, business models, conduct market assessments, policy advocacy, deploy decision making tools, amongst other solutions to advance SAREP's objectives through the SAREP Partnership Fund (SPF).

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Annexure

ANNEXURE I

Key Drone Hardware Manufactures

Major global and Indian players in hardware manufacturing are listed below

Key drone hardware manufacturers

S.NO.	FIRM	PARTICULARS
KEY GLOBAL FIRMS		
1.	DJI, China	• First drone manufacturer to launch commercial drone • DJI's Matrice 210 RTK V2, Matrice 300 RTK, and Mavic 2 Enterprise Advanced are used specifically for applications in the Energy sector such as solar inspections, construction, power grid management, power generation • DJI is also a software and service provider
2.	Parrot, France	• With ANAFI Ai, Parrot introduced the first commercial 4G UAV • Parrot has the largest partner ecosystem: from enterprise drone platforms, flight logs services (DroneLogbook, Airdata), public safety programs (DroneSense), advanced mission planning (QGroundControl, UgCS), to media, data cloud platforms (Survae), real-time geospatial situational awareness (Rapid Imaging, Textron Systems), surveying, and mapping (PIX4D)
3.	Yuneec, China	• Holds patents for its unmanned helicopter designs in Europe & USA • Yuneec's H520 is a Hexacopter with long flight times, safety & flexibility. It is developed for inspection, law enforcement, search & rescue, security, construction, and surveying & mapping applications across different sectors including energy
4.	Kespry, USA	• Provides drone-based aerial intelligence platform to aggregates, mining, construction, and surveying companies • Serves customers across North America, Europe, and Australia, including Colas, Grinnell Mutual, Lehigh Hanson/Heidelberg, Oldcastle, Titan America, XAP 360, and Zellstoff Celgar
5.	Autel Robotics, USA	• Their EVO II Series drones are purpose-built for automated and manual flight in law enforcement, fire, security, inspection, mapping & survey grade-capable data, with ingrained data security
6.	Skydio, USA	• Skydio's autonomous drones are used for Enterprise Inspection across Energy and Utilities, Telecommunications, Construction, and Transportation Infrastructure • Its Skydio 2 is built around the Skydio Autonomy Engine – the most advanced flying artificial intelligence system in the world • In March 2021, Skydio became the first US drone manufacturer to exceed $1 billion in value and is also a service provider
7.	Insitu Drones, USA	• Insitu designs, develops, and manufactures customized- a). hardware in the form of commercial-focused drones; b). software for extracting intelligence from raw data gathered by drones; and c). drone-related services for commercial applications such as surveying & reconnaissance • Their ScanEagle drone is designed for aerial imaging with diverse applications such as agricultural assessment, oil or gas pipeline inspection, and force protection
8.	Aerialtronics, Netherlands	• Their Altura Zenith combines state-of-the-art technology with a flat, compact, and lightweight design • Aerialtronics systems cater to a wide variety of segments including safety & security, inspection, surveying & mapping, agriculture, and research

S.NO.	FIRM	PARTICULARS
KEY INDIAN FIRMS		
1.	Defence Research and Development Organisation (DRDO)	• Manufactures drones only for India's Defence • Has launched multi-mission UAVs, namely Bharat and Nishant along with three other autonomous Micro & Miin UAVs, namely Black Kite, Golden Hawk, and Pushpak
2.	Paras Aerospace, Maharashtra	• Specializes in aerial mapping & surveying and offers complete UAV integration and UAV-based services for both hardware and software • Their products are designed to deal with a variety of situations and are best for Highway Mapping, Urban Mapping, Stockpile Calculations, Construction Monitoring and BIM, Slope Stability (Airport, Dams, Railway Tunnels), Energy (Powerline Infrastructure, Solar & Wind), Forestry, Plant Inspection (Power Plant, Oil, and Gas)
3.	Throttle Aerospace (TAS), Karnataka	• India's first DGCA approved drone maker for civil drones and has a license to manufacture military drones from MOD • Developing the state-of-art 10k sqft manufacturing facility, located in one of the largest industrial regions in Karnataka State; Kolar District; near Narsapura, India • Their Mapper Series Unmanned Aerial Systems are used to do topographical surveys, measurements, and extraction of volume in an open pit mine
4.	Garuda Aerospace, Tamil Nadu	• Focuses on the design, build, and customization of unmanned aerial vehicles (UAVs) or drones for various applications such as inspection in the energy sector, agriculture, disaster management, and solar cleaning • International standard certified company in ISO9001:2015 and AS9100 for Aerospace Quality Management Systems

Key Drone Software Providers

The list of major global and India drone software providers is listed below:

Key drone software providers for the power sector

S.NO.	FIRM	PARTICULARS
KEY GLOBAL FIRMS		
1.	Neurala, USA	• Proprietary AI platform to empower companies to automate visual inspections • Manufacturers around the world use Neurala's flagship VIA software to increase inspection rates and reduce product defects
2.	Propeller Aer, Australis	• Global leader in 3D mapping and data analytics solutions • Clientele- Hensel Phelps, Nevada Goldmines, Mc Connell Dowell, Orica, Suez Environment
3.	Slingshot Aerospace, USA	• Slingshot Aerospace develops computer vision-based solutions to extract intelligence and insights from ultra high-volume satellite, aerial, and drone imagery • Provides solutions to the US Department of Defense and industries such as insurance, financial services, and energy • Clientele- U.S, Airforce, NASA, Boeing, United States Space Force
4.	Dedrone, USA	• Market leader in smart airspace security, protecting organizations, property, and information against malicious drone threats using advanced hardware and software technology • Clientele- Korean Power Exchange, Neptune Terminals, Consolidated Edison Inc., Volke

S.NO.	FIRM	PARTICULARS
5.	Auterion, Switzerland	• Co-founded in 2017 by Lorenz Meier, creator of PX4 (the world's most widely used open-source drone autopilot operating system), Pixhawk, MAVLink, and QGroundControl • Provides an ecosystem of software-defined drones, payloads, and third party applications within a single easy to use a platform based on open-source standards
KEY INDIAN FIRMS		
1.	MapmyIndia, Delhi	• Offers advanced 2d and 3d maps, and AI-enabled geospatial technologies as well as IoT platforms and devices • Provides Drone services for GIS survey, mapping, security, surveillance, law enforcement, defense, and transportation purposes • Clientele- Amazon, McDonald's, GoI's Umang, Paytm, Apple
2.	Aesteria Aerospace Limited, Karnataka	• Robotics and artificial intelligence company that develops drone-based solutions to provide actionable intelligence from aerial data • SkyDeck, their end-to-end cloud-based drone operations platform streamlines drone operations and data management • Has in-house hardware design, software development, and manufacturing capabilities to serve customers across sectors such as agriculture, oil & gas, energy & utilities, telecommunications, mining, and construction

ANNEXURE II - REFERENCES

ABC News, 2020. *Intelligence bulletin reveals potential plot to disrupt US electrical grid.* [Online]
Available at: https://abcnews.go.com/WNT/video/intelligence-bulletin-reveals-potential-plot-disrupt-us-electrical-80961140
[Accessed 10 June 2022].
ABJ Drones, 2020. *ABJ Drones Case Study - 10MW Solar Panel Inspection in India.* [Online]
Available at: https://abjdrones.com/10mw-solar-panel-inspection-in-india/
[Accessed 10 June 2022].
Ball, M., 2021. *Case Study: Power Line Inspection with Drone LiDAR.* [Online]
Available at: https://www.unmannedsystemstechnology.com/2021/06/case-study-power-line-inspection-with-drone-lidar/
[Accessed 10 June 2022].
Bhatnagar, I. S., 2022. *Cost of training drone pilots set to reduce in coming days: Scindia.* [Online]
Available at: https://www.hindustantimes.com/india-news/cost-of-training-drone-pilots-set-to-reduce-in-coming-days-scindia-101652813739606.html
[Accessed 10 June 2022].
BloombergNEF (BNEF), 2020. *Power Sector To Spend $5 Billion on Software by 2025.* [Online]
Available at: https://about.bnef.com/blog/power-sector-to-spend-5-billion-on-software-by-2025/
[Accessed 10 June 2022].
Boukoberine, M. N., Zhou, Z. & Benbouzid, M., 2019. *A Critical Review on Unmanned Aerial Vehicles Power Supply and Energy Management: Solutions, Strategies, and Prospects.* [Online]
Available at:
https://www.researchgate.net/publication/335564429_A_Critical_Review_on_Unmanned_Aerial_Vehicles_Power_Supply_and_Energy_Management_Solutions_Strategies_and_Prospects
[Accessed 10 June 2022].
CEA, 2022. *Report on Reliability Index (RI) for the Year 2019-20.* [Online]
Available at: https://cea.nic.in/wp-content/uploads/dm/2022/03/DM_report_RI_2019_20_final.pdf
CyberHawk, n.d. *SSEN Transmission keep the power flowing with the early adoption of drones, IoT and visualization software.* [Online]
Available at: https://thecyberhawk.com/case_studies/ssen-transmission-keep-the-power-flowing-with-the-early-adoption-of-drones-iot-and-visualization-software/
[Accessed 10 June 2022].
Das Gupta, S., 2022. *RIL sets its drone biz plan in motion, looks to become a key player.* [Online]
Available at: https://www.business-standard.com/article/companies/ril-sets-its-drone-biz-plan-in-motion-looks-to-become-a-key-player-122021100046_1.html
[Accessed 10 June 2022].
DelAir, n.d. *RTE relies on Delair DT26X LiDAR drone for power line inspection.* [Online]
Available at: https://delair.aero/power-utilities/rte-relies-on-delair-dt26x-lidar-drone-for-power-line-inspection/
[Accessed 10 June 2022].
Delhi Electricity Regulatory Commission - DERC, 2022. *Suspension of Standards of Performance.* [Online]
Available at: http://www.derc.gov.in/sites/default/files/SoP%20Suspension%20Order%2010.01.2022.pdf
[Accessed 10 June 2022].
Dhasmana, I., 2019. *Business Standard.* [Online]
Available at: https://www.business-standard.com/article/economy-policy/we-look-forward-to-making-india-a-10-trillion-economy-says-pm-modi-119022300803_1.html
[Accessed 10 June 2022].
DigitalSky DGCA, n.d. *DigitalSky.* [Online]
Available at: https://digitalsky.dgca.gov.in/airspace-map/#/app
[Accessed 10 June 2022].
Drone Deploy Blog, 2017. *iSolara Improves Solar Design Workflow and Expedites Sales Process with Drone Maps.* [Online]
Available at: https://medium.com/aerial-acuity/isolara-improves-solar-design-workflow-and-expedites-sales-process-with-drone-maps-3ecc6a543041
[Accessed 10 June 2022].
Eagle CMMS, n.d. *Knowing the difference between Predictive, Preventive and Corrective Maintenance.* [Online]
Available at: https://www.eaglecmms.com/knowing-the-difference-between-predictive-preventive-and-corrective-maintenance/
[Accessed 10 June 2022].
Eckstein, D., Künzel, V. & Schäfer, L., 2021. *GLOBAL CLIMATE RISK INDEX 2021.* [Online]
Available at: https://germanwatch.org/sites/default/files/Global%20Climate%20Risk%20Index%202021_1.pdf
[Accessed 10 June 2022].
Engel, J., 2021. *Using drone LiDAR to improve powerline vegetation management.* [Online]
Available at: https://www.geobusinessshow.com/using-drone-lidar-to-improve-powerline-vegetation-management/
[Accessed 10 June 2022].
Equity Master, 2021. *6 Indian Companies Betting Big on Drones.* [Online]
Available at: https://www.equitymaster.com/detail.asp?date=12/08/2021&story=6&title=6-Indian-Companies-Betting-Big-on-

Drones
[Accessed 10 June 2022].
FlyAbility, n.d. *Inspection of a Nuclear Power plant.* [Online]
Available at: https://www.flyability.com/casestudies/inspection-of-a-nuclear-power-plant
[Accessed 10 June 2022].
Gao, M. et al., 2021. *Weather constraints on global drone flyability.* [Online]
Available at: https://www.researchgate.net/publication/352216248_Weather_constraints_on_global_drone_flyability
[Accessed 10 June 2022].
Gera, I., 2022. *India has added 34% more drone start-ups since new August guidelines.* [Online]
Available at: https://www.business-standard.com/article/economy-policy/india-has-added-34-more-drone-start-ups-since-new-august-guidelines-122021100820_1.html
[Accessed 10 June 2022].
Gridline - The magazine for landowners, 2017. *Pilot Project - Page 10 & 11.* [Online]
Available at: https://www.nationalgrid.com/electricity-transmission/document/92556/download
[Accessed 10 June 2022].
Grov, B., 2022. *This meter can give electricity customers a lower bill.* [Online]
Available at: https://www.nrk.no/vestland/denne-malaren-kan-gi-straumkundane-lagare-rekning-1.15883855
[Accessed 10 June 2022].
Huffman, G., n.d. *Burns McDonnell.* [Online]
Available at: https://amplifiedperspectives.burnsmcd.com/post/deploying-uavs-for-efficient-power-restoration-and-outage-prevention
[Accessed 10 June 2022].
Hussain, Z., 2022. *Indiatimes - Explained: The Evolution Of India's Drone Sector.* [Online]
Available at: https://www.indiatimes.com/explainers/news/drone-flying-in-india-561007.html#Indias_history_of_drones
[Accessed 10 June 2022].
Iberdrola, n.d. *Inspection with Drones - We are committed to using drones to inspect wind farms.* [Online]
Available at: https://www.iberdrola.com/innovation/drones-wind-farms
[Accessed 10 June 2022].
India Today, 2020. *Now, Drones to monitor Power Theft.* [Online]
Available at: https://www.indiatoday.in/mail-today/story/now-drones-monitor-power-theft-1648532-2020-02-21
[Accessed 10 June 2022].
India Today, 2022. *IIT Roorkee to provide drone training in India.* [Online]
Available at: https://www.indiatoday.in/education-today/news/story/iit-roorkee-to-provide-drone-training-in-india-1951557-2022-05-19
[Accessed 10 June 2022].
Innoter.com, n.d. *Innoter products - DTM generation.* [Online]
Available at: https://innoter.com/en/products/spatial-data/dtm-generation/
[Accessed 10 June 2022].
International Energy Agency, 2021. *India Energy Outlook 2021.* [Online]
Available at: https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf
[Accessed 10 June 2022].
Kislay, K., 2021. *How Drones are Revolutionising the Power Sector.* [Online]
Available at: https://www.energetica-india.net/articles/how-drones-are-revolutionising-the-power-sector#:~:text=Evolution%20of%20drones%20in%20the%20Indian%20Ecosystem%20India’s,step-by-step%20regulations%20are%20being%20created%20to%20monitor%20drones
[Accessed 10 June 2022].
Ministry of Civil Aviation - PIB Delhi, 2021. *PRL - Government Approves PLI Scheme for Drones and Drone Components.* [Online]
Available at: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1755157
[Accessed 10 June 2022].
Ministry of Civil Aviation - PIB, 2021. *PRL - Government Approves PLI Scheme for Drones and Drone Components.* [Online]
Available at: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1755157
[Accessed 10 June 2022].
Ministry of Civil Aviation - PIB, 2021. *PRL - Ministry of Civil Aviation notifies liberalised Drone Rules, 2021.* [Online]
Available at: https://pib.gov.in/PressReleasePage.aspx?PRID=1749154
[Accessed 10 June 2022].
Ministry of Civil Aviation, 2021. *National Unmanned Aircraft System Traffic Management (UTM) Policy Framework.* [Online]
Available at: https://www.civilaviation.gov.in/sites/default/files/National-UTM-Policy-Framework-2021_24_Oct_2021.pdf
[Accessed 10 June 2022].
Ministry of Civil Aviation, 2021. *The Drone Rules, 2021.* [Online]
Available at: https://egazette.nic.in/WriteReadData/2021/229221.pdf
[Accessed 22 January 2022].
Ministry of Civil Aviation, 2022. *Certification Scheme for Unmanned Aircraft Systems.* [Online]
Available at: https://qcin.org/certification-scheme-for-unmanned-aircraft-systems-(uas)

Ministry of Power, 2021. *Office Memorandum.* [Online]
Available at: https://powermin.gov.in/sites/default/files/uploads/OM_Revamped_Distribution_Sector_Scheme.pdf
Ministry of Power, 2022. *Tenth Annual Integrated Rating and Ranking of Power Distribution Utilities,* s.l.: s.n.
MPERC, n.d. *MP Retail Tariff for FY 2019-20.* [Online]
Available at: http://www.mperc.in/State%20Discoms%20Retail%20Supply%20Order%20for%20FY%202019-20.pdf
National Smart Grid Mission, n.d. *Smart Grid Awareness.* [Online]
Available at: https://www.nsgm.gov.in/en/smart-grid
[Accessed 10 June 2022].
Nazir, T., 2022. *The Logical Indian - Haryana to come up with Training Institute for Drone Pilots.* [Online]
Available at: https://thelogicalindian.com/good-governance/haryana-institute-for-drone-pilots-35019
[Accessed 10 June 2022].
Netter, P., 2020. [Online]
Available at: https://energized.edison.com/stories/drones-take-sces-dam-safety-inspections-to-new-heights
[Accessed 10 June 2022].
Netter, P., 2021. *Drones and AI: Future is Now for SCE's Aerial Inspections.* [Online]
Available at: https://energized.edison.com/stories/drones-and-ai-future-is-now-for-sces-aerial-inspections
[Accessed 16 January 2022].
Onag, G., 2020. *ABI Research: Drone market worth US$92 billion by 2030.* [Online]
Available at: https://futureiot.tech/abi-research-drone-market-worth-us92-billion-by-2030/
[Accessed 10 June 2022].
Pandey, A., 2021. *Telangana uses drones to inspect power lines and towers, project expected to be scaled up.* [Online]
Available at: https://www.indiatoday.in/india/story/telangana-drones-inspect-power-lines-towers-project-scaled-up-1877532-2021-11-17
[Accessed 10 June 2022].
PFC, 2020. *Performance Report of Power Utilities.* [Online]
Available at: https://www.pfcindia.com/Home/VS/29
[Accessed 10 June 2022].
PFC, n.d. *Input Formats for State Distribution Utilities.* [Online]
Available at: https://www.pfcindia.com/Home/VS/10239
[Accessed 10 June 2022].
PFC, n.d. *Input Formats for State Distribution Utilities.* [Online]
Available at: https://www.pfcindia.com/Home/VS/10239
[Accessed 10 June 2022].
PIB - Ministry of Civil Aviation, 2021. *Ministry of Civil Aviation releases India's airspace map for drone operations.* [Online]
Available at: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1757850
[Accessed 10 June 2022].
Press Information Bureau - PIB, 2021. *Ministry of Civil Aviation releases India's airspace map for drone operations.* [Online]
Available at: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1757850
[Accessed 10 June 2022].
Radišić, T., Vidović, A., Ivošević , J. & Wang , B., 2018. *Challenges and Solutions for Urban UAV Operations.* [Online]
Available at:
https://www.researchgate.net/publication/326319889_Challenges_and_Solutions_for_Urban_UAV_Operations
[Accessed 10 June 2022].
Singh, I., 2022. *Done DJ - Sweden escalates 'drone hunt' as more illegal flights are spotted over nuclear sites, palaces.* [Online]
Available at: https://dronedj.com/2022/01/18/sweden-drone-nuclear-sites/
[Accessed 10 June 2022].
SME Times, 2021. *NTPC.9.Thmb.jpg NTPC to use drones to detect encroachments, solar panel damage etc..* [Online]
Available at: http://www.smetimes.in/smetimes/news/indian-economy-news/2021/Jul/31/ntpc-drone68096.html
[Accessed 10 June 2022].
Sterlite Power, 2020. *Overcoming the Transmission Challenges with Technology.* [Online]
Available at: https://www.sterlitepower.com/blog/overcoming-the-transmission-challenges-with-technology
[Accessed 10 June 2022].
Sterlite Power, n.d. *Drone Usage in Transmission Line Industry.* [Online]
Available at: https://www.saarcenergy.org/wp-content/uploads/2021/09/Sterlite-India-presentation.pdf
[Accessed 10 June 2022].
Sultan, S., 2022. *Cybersecurity Concerns in Surveillance Drones.* [Online]
Available at: https://www.ijert.org/cybersecurity-concerns-in-surveillance-drones
[Accessed 10 June 2022].
Sur, A., 2022. *Understanding Tata Power's drone plans to maintain power lines, prevent thefts.* [Online]
Available at: https://www.moneycontrol.com/news/business/exclusive-inside-tata-powers-plan-to-take-up-drone-ops-for-maintaining-power-lines-preventing-thefts-8669321.html
Swidch, 2021. *The three key challenges facing today's Drone industry.* [Online]
Available at: https://www.swidch.com/blogs/three-key-challenges-facing-the-drone-industry
[Accessed 10 June 2022].
T&D World, 2022. *Heimdall Power Successfully Installs IoT Sensor by Drone on Powered Line.* [Online]
Available at: https://www.tdworld.com/overhead-transmission/article/21239196/heimdall-power-successfully-installs-iot-

sensor-by-drone-on-powered-line
[Accessed 10 June 2022].
T&D World, 2022. *Heimdall Power Successfully Installs IoT Sensor by Drone on Powered Line.* [Online]
Available at: https://www.tdworld.com/overhead-transmission/article/21239196/heimdall-power-successfully-installs-iot-sensor-by-drone-on-powered-line
[Accessed 10 June 2022].
The Explorer, n.d. *Using drones to monitor sulphur emissions from ships.* [Online]
Available at: https://www.theexplorer.no/solutions/using-drones-to-monitor-sulphur-emissions-from-ships/
[Accessed 10 June 2022].
The legal Drone, n.d. *Weather for Drone Pilots.* [Online]
Available at: https://thelegaldrone.com/weather-for-drone-pilots/
[Accessed 10 June 2022].
Torró, R., 2018. *Vegetation Management for Utilities Using Lidar Data.* [Online]
Available at: https://www.gim-international.com/content/article/vegetation-management-for-utilities-using-lidar-data
[Accessed 10 June 2022].
UAV Huanqiu, 2018. *Outlook 2018: Application and Prospects of UAVs in the Field of Electric Power Inspection.* [Online]
Available at: https://uav.huanqiu.com/article/9CaKrnK6mtN
[Accessed 10 June 2022].
Vats, A., 2021. *The road ahead for drone regulations in India.* [Online]
Available at: https://www.orfonline.org/expert-speak/the-road-ahead-for-drone-regulations-in-india/
[Accessed 10 June 2022].
VCT Group, n.d. *Solar Performance Diagnostics.* [Online]
Available at: https://vctgroup.com/solar-diagnostics/
[Accessed 10 June 2022].
Vidrona, n.d. *AI Powered Predictive Prescriptive Analytics for Utilities.* [Online]
Available at: http://vidrona.com
[Accessed 10 June 2022].
Yue, Y., 2021. *The Value of Unmanned Aerial Systems for Power Utilities in Developing Asia.* [Online]
Available at: https://www.adb.org/publications/unmanned-aerial-systems-power-utilities-asia
[Accessed 10 June 2022].

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