



Model Terms of Reference for Drone based Asset Management

Noida Smart Distribution Project

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1. Introduction and General information

1.1 Introduction

Drones are emerging as versatile monitoring tools across different sectors such as 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 adoption in civilian applications. A broad spectrum of commercial drone applications exists today, including inspection, monitoring, data collection, search, and rescue.

Drone applications, equipped with Artificial Intelligence and Machine Learning (AI / ML) capabilities are gaining acceptance in the power sector globally. Utility service providers and developers in India are exploring the use of drone-based applications to improve processes. Some of the early adopters of drone applications in India include transmission utilities and renewable energy project developers however distribution utilities have not ventured into adoption of its application at a large scale yet.

The Indian power distribution sector remains a weak link in the electricity supply chain. Most power distribution companies (Discoms) face challenges such as inadequate capacity, aging infrastructure, obsolete asset management practices, high technical losses, power theft, and low investment in modernization. These challenges affect the operational and financial health of the Discoms.

Thus, Discoms are ideal candidates for drone technology deployment to improve their operational efficiency. Some utilities have already implemented small-scale pilot projects to establish the viability and use cases of drone applications. Typical areas of interest for Discoms are - defect detection, asset management, predictive maintenance, and predictive theft detection.

Drone based asset monitoring is a modern way of maintaining the network in robust health condition with minimum human intervention in identifying existing and probable pain areas. It seamlessly captures the 360 - degree images of assets, process the data in AI/ML platform and provides comprehensive defect list based in order of severity i.e., Highly critical, Critical, less critical.

In Noida area, 33kV and 11kV distribution lines are prone to defects, leading to downtime and operational disruptions. Introducing drone-based asset management can be pivotal in minimizing such issues. Drones equipped with advanced sensors can conduct proactive inspections, identifying potential defects before they escalate. For instance, identifying worn-out insulators, damaged conductors, or loose nut-bolts, connections in a timely manner allows preemptive maintenance. This shall reduce downtime and ensure continuous power supply to consumers. This proactive approach aligns with modern technological solutions, enhancing the reliability and efficiency of the distribution network.

1.2 Drone deployment for asset monitoring

Drone operations are scheduled at periodic intervals to gauge the condition of assets by capturing high- resolution images and videos through aerial surveys. Typically, thousands of high-resolution images are captured during the drone operations covering each asset and the data is processed and analyzed through AI / ML algorithms. The AI / ML algorithms process images, compare them with standard design specifications and run diagnostic analysis for detection of defects or weak links in the asset ecosystem. Once the gap / defect is identified, the AI / ML algorithms further provide actionable insights for maintenance actions and optimal resource utilization plan based on the severity of defects.

Maintaining asset health is crucial aspect in reducing unplanned outages, tripping, maintenance costs and enhancing overall system reliability. Discoms can redefine the asset management and maintenance through periodic monitoring and predictive assessment of existing and probable defects in assets across the network.

1.3 Objective

PVVNL proposes to demonstrate drone-based asset management solution for 200 ckms of 33 kV lines in Noida. Additional coverage of 11 kV and LT lines may be undertaken in the pilot demonstration based on discussion with nodal officer / PMU of PVVNL.

Drone based asset health management solution shall cover the following

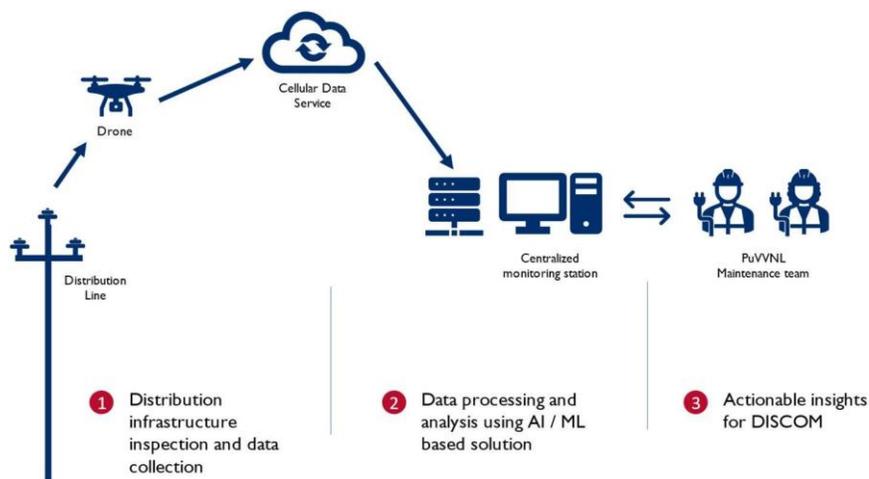
- Condition monitoring of 33 kV, 11 kV and LT Lines including poles, conductors, insulators, etc.
- Condition monitoring of Distribution Transformers (DTs)
- Vegetation monitoring
- On-ground asset location offset cases

The following benefits are envisaged for PVVNL:

- Reduction in yearly feeder tripping (nos.)
- Reduction in DT failure % and reduced system down-time
- Reduction in ENS (Energy Not Served)
- Detection of theft cases / hooking (nos.) from the LT poles / DTs in the project area
- Cost saving on repair and maintenance
- Increased asset availability and reliability
- Reduction in AT&C loss
- Reduction in O&M expenses on account of asset damage, failures
- Correct GIS mapping of assets
- Improved reliability parameters such as SAIDI, SAIFI
- Improved Health and Safety of personnel

1.3 Schematic diagram

Schematic diagram of the Distribution based Asset Health Monitoring solution is as follows:



2. Scope of work

The bidder is required to provide an unpriced Bill of Quantity (BoQ) for the Drone based asset management solution. This unpriced BoQ must state all the line items influencing the development of the solution as defined in this scope of work.

The following sub-sections provide an overview of the scope of work for the Drone based Asset Health Management solution:

2.1 Shortlisting site location and baselining for pilot

The selected bidder / implementing agency shall assist PVVNL in formulating criteria of shortlisting the target network (area and voltage level) for drone-based asset health management solution. For instance, areas with high outage hours, or areas with high AT&C losses may be prioritized. For reference, it is estimated that PVVNL has around 222 ckms of 33kV network in Noida.

The selected bidder / implementing agency shall assist in baselining of data i.e., type and no. of assets under the shortlisted areas such as Distribution Transformers, Poles, Towers, etc. Baselining shall also be required for measuring success indicators of the project such as DT failure %, No. of outages, Energy Not Served (ENS), SAIDI, SAIFI, etc.

Post formulation of the shortlisting criteria, PVVNL shall provide the required data enabling the selected bidder / implementing agency to finalize the assets covered under pilot implementation of the drone-based asset health management solution.

2.2 Kick-off and approvals

The selected bidder / implementing agency shall perform the following activities during the initial phase of the project:

Stage	Activities
Kick-off meeting	<ul style="list-style-type: none"> a. Presenting the approach and methodology to PVVNL during the kick-off meeting b. Assist PVVNL in shortlisting the lines / areas to be covered in the scope c. Share and submit data requirements from Discom such as KML / KMZ (GIS files) for assets covered in shortlisted lines / areas d. Develop inspection plan with feeder/substation-wise timelines and obtain approval from PVVNL on the proposed inspection plan e. Conduct actual inspection on site
Post inspection	<ul style="list-style-type: none"> f. Validate correctness of asset locations for sample cases g. Develop baseline data for success indicators (please see section 2.4) h. Obtain approval from PVVNL on success indicators and baseline data

2.3 Selection of Drone based solution type specification

Most of the available drone solutions in the market offer a SaaS based analytics solution which works in OPEX mode. An alternative approach for drone-based solution could be CAPEX mode where PVVNL itself procures and operates the drones - subscribing for periodic services of SaaS based analytics solution.

Suggested specifications and basic requirements of drone-based asset management solution are as follows:

Device Name	Suggested Specifications
UAV (Drone)	<ul style="list-style-type: none"> ▪ Type of drone i.e. Multi rotor ▪ Range- 5 km ▪ Maximum single flight time- 30 min, 60 min
Sensors	Type of Sensor with functionality- <ul style="list-style-type: none"> ▪ RGB (Red Green Blue) sensor ▪ Infrared sensor ▪ LiDAR (Light Detection And Ranging) ▪ Multispectral sensor ▪ Obstacle avoidance sensor

2.4 Baselineing of parameters

The selected bidder / implementing agency shall support PVVNL in choosing and baselineing of parameters which shall be used for cost benefit analysis and success indicators. Few suggested parameters are as follows:

- Annual no. of outages for (33 kV, 11 kV feeder covered in scope)
- Annual maintenance cost for assets such as jumpers, insulators, conductors (INR. Cr.)
- Annual asset replacement / augmentation cost (INR. Cr.)
- Technical loss (%) (if calculated)
- Annual no. of theft cases reported (in case of LT network)

**The measurement of the success indicators may commence 3 months after the first inspection report generation*

2.5 Site demonstration

The selected bidder / implementing agency shall arrange a demonstration at one of the site locations agreed by the nodal officer of PVVNL. The demonstration shall cover drone flying capability of crew and Standard Operating Procedure (SOP) followed during drone survey. This shall be conducted in presence of team identified by the nodal officer of PVVNL.

The process of demonstration shall comprise of the following as minimum:

1. Demonstration of drone operation for all activities from take-off to landing including image / video capturing.
2. Demonstration of all features of the display, dashboard, and report generation and all other software maintenance features.
3. Validation of defects identified through drone survey jointly by vendor and PVVNL team.
4. Demonstration and access of mobile application for locating assets with defect severity level to PVVNL's nodal officer and operations team.

2.6 Drone survey plan

Post demonstration, the selected bidder / implementing agency shall prepare and present a detailed drone survey plan to PVVNL. In preparing the plan, the implementing agency shall take all kinds of scenarios into consideration. Frequency of drone surveys depends upon multiple factors. These include geographical terrain, line accessibility, data capturing and processing time for corrective action on identified defects by the operations team. Moreover, the plan has to consider specific days when

drone operation might not be allowed due to Government restriction, local / state / national election days, state holidays and on extreme weather days, which may hamper drone flying.

Additionally, drone surveys are effective when planned in sync with seasonal cycles i.e., pre-monsoon, post-monsoon, etc. to understand seasonal impact on defect occurrence, frequency, and severity. Based on these factors, different scenarios can be designed for drone survey planning.

The selected bidder / implementing agency and the nodal officer / PMU of PVVNL shall decide and mutually agree on the best possible plan based on resource optimization and maximum returns / benefit to PVVNL.

2.7 Integration with other technologies

Drone based asset management solution is envisaged as a standalone analytics software solution which has a feature of analyzing the high-resolution images and videos based on AI / ML model. The solution is not required to provide any real-time monitoring or control of assets. Thus, integration with other technologies such as SCADA / DMS / OMS is not required.

2.8 Operating the solution for stated period

The selected bidder / implementing agency shall own and operate the Drone based Asset Management solution for a period of one (1) year after commissioning. This includes the dashboard and mobile application as a part of the solution. After this period, the PVVNL shall decide on continuation and further scale-up of the solution. Such decision may be based on the results of the pilot project. In case of dashboard and data server being hosted at vendor's end, data retention for six months shall be ensured post completion of pilot project period.

2.9 Data analytics (AI / ML) for images / video

An AI / ML based analytics software shall be deployed to process the high-resolution images, videos and associated asset data collected from site. Besides visual defects, drones shall monitor the temperature of distribution assets using thermographic camera for hotspot detection and maintenance requirements. This data can be further processed by the AI / ML algorithm to establish historical patterns for network assets. The software shall conduct predictive defect analysis and generate actionable insights for maintenance actions. AI/ML logic shall incorporate new defects as identified by User i.e. PVVNL and update in logic for detection of actionable jobs.

Subsequently, based on the trend progression, a prognostic analysis for arresting and reversing the abnormal occurrences shall be undertaken. The generated report shall prioritize defects based on severity level of urgency of maintenance. It shall also clearly state the kind / nature of maintenance required for each defect. For instance, a pin insulator crack may require immediate attention to avoid line breakdown - hence the severity level is high. Maintenance action required in this case is - Pin insulator replacement. Thus, defect description and severity must be provided for clear and concise explanation.

By use of AI / ML algorithms, evidence-driven and location-specific intelligence shall be collated for review of PVVNL. This shall prompt organization-wide corrective actions to improve planning and design of the network, assets, and component level.

2.10 Analytics dashboard front-end (SaaS)

The AI / ML algorithm mentioned above shall be tied to an analytics dashboard front-end with requisite user access to PVVNL. The cloud hosted analytics dashboard shall include the following minimum features:

- Facility of uploading & downloading GIS files for shortlisted network / area

- Enable the users to have a repository of data and perform various functions such as annotation, marking, zooming in, zooming out, applying filters, comments, etc.
- Generate customized reports in the required format(s)
- Provide on-demand reports (.pdf/.xlsx) prioritizing the severity and criticality of defects.
- Provide a dedicated screen to log the defect rectification completion
- Provide visualization of video along with Map, which provides the point of interest (Pol) as a marker on the map
- Global Navigation Satellite Systems (GNSS) based asset offset cases for corrective action

The dashboard may be hosted at PVVNL's CMU / SDCC. Alternatively, PVVNL may direct the selected bidder / implementing agency to host the solution at a suitable cloud hosting platform. Access shall be provided to selected PVVNL officials as directed by nodal officer.

2.11 Data security

The selected bidder / implementing agency shall maintain strict confidentiality of all information including but not limited to documents, data, and outcomes relevant to project. Suitable NDA may be signed to ensure Data and information protection.

2.12 Handling of data

All the data and related reports shall be shared with the nodal officer of PVVNL on quarterly basis or as per the period mentioned in contract with acceptance of PVVNL. Sensitive data shall be encrypted and kept in a cloud storage service. Relevant formats shall be shared with the nodal officer for handover of data for each period together with signoff.

The following steps shall be taken in handling the data:

Data Pre-processing

Data pre-processing involves cleaning, transforming, and organizing raw data to enhance its quality and usability. Tasks include handling missing values, removing outliers, normalizing variables, and encoding categorical data. This prepares the data for analysis, ensuring accurate insights and improved machine learning model performance.

Data Back-up

Before commencing of the data processing activity, vendor must ensure to create and keep a raw back-up data. This shall help in mitigating the risk of data loss and any need to recapture data. Backup data also allows vendor to make copies of the raw data to enable simultaneous algorithms to run for various defects at the same time.

Data Handover

The vendor shall retain the backup data till 6 months post completion of the project. All the data related to project- images and videos captured during survey, dashboard reports etc. to be handed over to nodal officer of PVVNL through zip files on physical hard disk or shared path on cloud drive.

2.13 Reports

The following reports shall be generated as a minimum -

1. Condition of insulators, conductors, jumpers, ground / pole structures, joints of conductors, etc. for any type of fault, leakage, cut, damage.
2. Hot-spot analysis of all the assets across the inspected line

3. Line-wise and asset-wise list of faults with criticality level, GPS coordinates and nearby asset / landmark for easy access
4. List of assets on baseline date with their on-ground location
5. Cost benefit analysis report considering, but not limited to the following:
 - Cost of pilot project considering hardware, software, and costs under capex and Opex scenarios
 - Benefits from improved detection of assets requiring immediate preventive maintenance.
 - Reduced labor cost of crews to perform periodic inspections.
 - Reduced cost of repairing / replacing assets
 - Improved revenues due to reduction in asset failures, tripping, and reduction in Energy Not Served (ENS).

2.14 Generation of actionable insight list

As mentioned above, the solution shall provide actionable insights derived from data using AI / ML models. Insights refer to specific, valuable, and practical pieces of information that are generated through the analysis of complex datasets. Thus, insights list shall cover a clear understanding of:

- a. What is the defect?
- b. Where is the defect?
- c. When can the defect cause breakdown (indicative)?
- d. How to repair the defect? (Offering concrete steps or recommendations)

The recommendations shall enable informed decision-making and guide actions that lead to tangible outcomes and improvements for PVVNL and consumers. For instance, an **Optimal Maintenance Schedule** may be recommended. This predicts the likelihood of equipment/component level failures and recommends a maintenance schedule to proactively address high-risk assets, reducing downtime.

2.15 Illustrative list of assets to be covered under the project

An illustrative list of assets to be covered for the pilot project is given below. This list can be modified subjected to PVVNL's preference before finalizing action plan.

- Tower / Pole structure
- Insulators (defects such as cracking / chipping)
- Conductors and Jumpers (defects such as cuts / breaks)
- Distribution Transformers (DT)
- Circuit Breakers and isolators
- Auto-reclosures and sectionalizers (if installed)
- Spacers
- Danger board / Anti-climbing device
- Earth wire and stay wire
- Nuts and bolts (defects such as loosening)
- Cross Arm

2.16 Defect geolocation

The solution must have the capability of providing defect geolocation. Usually, defects are located on the assets which are remotely located. Therefore, access to information on geo-location of the assets shall help the maintenance team to attend the defects in an orderly fashion and time.

Key aspects of fault geolocation include:

Geospatial Data: Utilizing geospatial data, such as GPS coordinates, geographic information system (GIS) mapping, satellite imagery, or location-based services, to pinpoint the exact location of the fault.

Mapping Tools: Employing specialized software or tools that integrate geolocation data and allow users to visualize faults on maps, enabling a clear understanding of the fault's geographical context.

Remote Sensing: Utilizing remote sensing capability of drones to gather geospatial data pertaining to an asset

For distributed systems, such as Discom's power grids networks, fault geolocation helps identify the specific segment or node where a fault has occurred, expediting repair and restoration efforts. In critical situations, like natural disasters or accidents, fault geolocation helps emergency responders quickly locate and address issues minimizing damage. Geolocation data aids in planning maintenance activities, as it allows organizations to efficiently allocate resources and prioritize tasks based on the proximity and severity of defects.

2.17 Monitoring and evaluation

In order to monitor, evaluate and improve the Drone based asset management solution the selected bidder / implementing agency shall deploy a suitable team, stationed at PVVNL, Noida. This team shall coordinate with nodal officer of PVVNL on a regular basis. Review methodology and frequency of review shall be defined in consultation with nodal officer of PVVNL.

3. Documentation requirements

The selected bidder / implementing agency shall be required to maintain and produce the following documents -

- Baseline data details for no. of sub-stations, feeders, DT's, lines and other assets covered under the project scope
- Drone flying authorization from appropriate authority such as Directorate General of Civil Aviation (DGCA) as applicable for Noida
- Letter of authorization from PVVNL to the vendor for conducting project activities at project site.
- Permission letter from local administration for drone operation as per appropriate flying zone
- Type of reports in mutually agreed format with nodal officer of PVVNL
- Sign-off document to validate mutually agreed success indicators for project evaluation
- Periodic defect list reports based on each drone inspection covering all assets and parameters as defined under the project scope
- Monthly reports on mutually defined KPIs in prescribed format
- Standard Operating Procedure of drone operation

4. Training and Safety

4.1 Training requirements

The selected bidder / implementing agency shall organize training to the core group of implementation team of PVVNL as well as end user training. Representatives from the selected bidder / implementing agency, Purchaser's implementation project and change management teams shall be involved throughout in the development of training strategy, training material design and development, standards, and training delivery to ensure that change management issues are incorporated, and that training strategies and materials are aligned to the requirements of the project and as business specific as possible. This includes but is not limited to, training of user interface for using dashboard for customization of reports, data extraction, data analysis through image repository etc.

4.2 Operational safety

1. The selected bidder / implementing agency shall be responsible for maintaining safety related to site, infrastructure, and manpower during complete drone operations from take-off till landing during each round of arial survey.
2. During drone operation, minimum clearance must be maintained from live network, all electrical assets and establishments, sensitive buildings (religious places) and living beings.
3. Standard Operating Procedure and risk mitigation plan must be shared with PVVNL's nodal officer.
4. Hazard identification and risk assessment shall be conducted prior to undertaking any site activity and proper Personal Protective Equipment (PPEs), training and implements shall be provided to drone operation team and concerned PVVNL operations staff.
5. The selected bidder / implementing agency shall indemnify PVVNL from any loss of property and life during drone operations at project site.

5. Deliverables

The following deliverables shall be expected from the selected bidder / implementing agency

No.	Deliverable
D1	<p>Work plan & kick-off</p> <ul style="list-style-type: none"> • Approach and Methodology outlining how the selected bidder / implementing agency shall accomplish all the tasks illustrated in the Scope of Work within the due deadlines • List of required data, data collection, development of templates to obtain inputs from PVVNL • Identification and finalization of project area along with details of assets • Inspection plan submission and approval
D2	<p>Post inspection activities and Inception report</p> <ul style="list-style-type: none"> • Baseline data for success indicators • Validation of field assets based on ground inspection • Identification of sensitive establishments, buildings and areas under project scope • Presentation and approval on above points through submission of Inception report

No.	Deliverable
D3	<p>Periodic inspection reports based on AI based analysis</p> <ul style="list-style-type: none"> ▪ Periodic inspection for data collection for condition monitoring of assets, defects, vegetation management and theft detection ▪ High resolution images and videos of inspection ▪ Inspection report for each quarter summarizing the findings ▪ Asset offset cases based on drone survey and geo-location ▪ Different reports covering all type of defects such as Hotspot, damage, cuts, loose joints, etc. ▪ List of recommendations, insights and reports on assets, defects, vegetation status and theft case ▪ Summarized findings and actionable insights
D4	<p>Monthly reports on Success indicators</p> <ul style="list-style-type: none"> • Monthly report on success indicators such as Reduction in No. of Outages, Outage Hours, ENS, AT&C loss %, etc. to be shared in pre-defined format (as agreed with Nodal officer of PVVNL) • Monthly Cost benefit analysis • Support to PVVNL in applying the recommendations based on output of analysis (if required) • Evaluation and validation of report outcomes <i>(Refer to section 2.4 for baseline parameters and success indicators)</i>
D5	<p>Pilot assessment, Cost-benefit analysis and completion sign off with showcasing of results to PVVNL</p> <ul style="list-style-type: none"> • Final Cost-benefit analysis • Sign-off and approval from PVVNL on pilot results • Presentation on project experience and key highlights to PVVNL in Dissemination workshop