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POWERING THE FUTURE: A COMPREHENSIVE STUDY ON UPGRADING CHHATRAPATI SAMBHAJI NAGAR'S TRANSMISSION INFRASTRUCTURE

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ABSTRACT

This paper presents a comprehensive analysis of the 132kV and 220kV substations in Chhatrapati Sambhaji Nagar, Maharashtra, under the operational jurisdiction of MSETCL (Maharashtra State Electricity Transmission Company Limited). With a view towards enhancing network reliability, addressing load growth, and preparing for future urban and industrial demands, a new network proposal is presented. This proposal aligns with the upcoming State Transmission Utility (STU) plan and aims to improve transmission efficiency through strategic substation upgrades, the formation of a 132kV ring network, and optimal feeder realignments.

Keywords: MSETCL, MSEDCL, STU, Loading, Transformers, DMIC *etc*.

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I. INTRODUCTION

The growing industrial and urban development in Chhatrapati Sambhaji Nagar (formerly Aurangabad), Maharashtra, has placed immense pressure on the region's electrical infrastructure. This city, known for its strategic location in the Delhi-Mumbai Industrial Corridor (DMIC), has been witnessing significant industrial activity and urban expansion, resulting in rapidly escalating power demands. The current transmission infrastructure, managed by the Maharashtra State Electricity Transmission Company Limited (MSETCL), is comprised of a network of 132kV and 220kV substations and feeders.

These substations supply power to key industrial zones, such as the Shendra MIDC, as well as the urban and semi-urban regions of the city and its surrounding areas.

However, this network is increasingly becoming inadequate to meet the growing demands. Many of the existing substations, such as 132kV Chikalthana and 220kV Shendra, are operating near their maximum load capacity, with limited scope for further expansion under the current configuration. The dependency of some substations on a single power source, particularly the reliance of 220kV Shendra on the 400kV PGCIL Chittepimpalgaon substation, further compounds the risk of outages and supply instability.

The existing infrastructure also poses several challenges to operational efficiency. Radially fed substations, such as 132kV Satara and 220kV Shendra, lack alternative sources of power, leading to increased vulnerability during outages or maintenance. Additionally, as the industrial and residential areas expand, the load on these substations is expected to increase exponentially, which will further strain the existing system. Moreover, the feeder configurations, particularly at the 11kV and 33kV levels, need realignment to optimize load distribution and reduce transmission losses.

This paper provides a detailed study of the existing 132kV and 220kV transmission network in Chhatrapati Sambhaji Nagar and proposes a series of strategic upgrades and network enhancements. These recommendations are designed to improve system reliability, accommodate anticipated load growth, and future-proof the infrastructure for the coming decades. Specifically, this study focuses on:

- Forming a 132kV ring network to better distribute urban loads.
- Reinforcing the 220kV network through additional substations and feeder realignments.
- Proposing the upgrade of key substations, such as the 220kV Bidkin substation, to 400kV to cater to the industrial expansion of the DMIC.
- Addressing the need for alternative power sources to reduce dependency on single substation nodes, thereby improving network resilience.

The proposed network restructuring not only addresses the immediate needs of the city's growing population and industrial activities but also provides a sustainable and scalable solution to future power requirements. This study will serve as a guiding framework for MSETCL's future transmission development projects, ensuring that the electrical infrastructure evolves in tandem with the city's growth trajectory.

II. LITERATURE REVIEW

The transmission and distribution of electrical power in urban and industrial regions are subject to several technical and logistical challenges, particularly in rapidly developing areas like Chhatrapati Sambhaji Nagar. The optimization of load flow, command area radius, and the distance-related power capacity of substations are critical factors in maintaining an efficient and reliable power supply. This literature review explores the existing research and technical frameworks surrounding these elements, providing context for the proposed upgrades in this study.

2.1 Load Flow Studies and Power Distribution Optimization

Load flow studies are fundamental to power system planning and operation. These studies focus on the distribution of active and reactive power, voltage profiles, and the efficient utilization of power system infrastructure. Various models, such as Newton-Raphson and Gauss-Seidel methods, have been used to conduct load flow analyses in large interconnected power systems.

According to Singh et al. (2017), load flow studies are essential for determining the best configuration of substations and feeders to ensure that voltage levels remain within acceptable limits while minimizing power losses. The study also suggests that implementing load flow optimization at both the planning and operational stages leads to significant improvements in system stability.

In the case of Chhatrapati Sambhaji Nagar, load flow analysis is particularly important due to the radial nature of many of its substations, such as 132kV Satara and 220kV Shendra. Radial systems, which lack redundancy, are vulnerable to outages when faults occur, affecting the overall reliability of the system. Research by Adepoju et al. (2019) highlights the need for alternative power sources in such radial systems to reduce downtime and maintain a stable voltage profile during high-demand periods. The formation of a 132kV ring network, as proposed in this study, addresses this issue by creating alternative paths for power flow and enhancing system redundancy.

2.2 Substation Capacity and MW-Distance Power Flow

The capacity of substations, in terms of both megawatt (MW) load and distance from load centers, is another critical consideration in network planning. Studies indicate that the distance between the substation and the load center directly impacts power losses and voltage drops. According to Glover et al. (2012), for every kilometer of distance from the substation, the power losses increase significantly, particularly at lower voltage levels like 33kV and 11kV. This phenomenon, referred to as MW-distance capacity, is a crucial factor when deciding the placement of new substations or upgrading existing ones.

Research by Alam et al. (2020) suggests that increasing the number of substations and reducing the distance between substations and load centers significantly enhances power efficiency and reduces operational costs.

2.3 Command Area Radius of Substations

The concept of a substation’s command area radius refers to the geographical area that can be efficiently served by the substation without exceeding its voltage and capacity limits. Studies by Das et al. (2015) indicate that for 132kV substations, the effective command area radius typically extends up to 10-15 kilometers, depending on the load density and feeder configuration. For 220kV substations, the command area radius can extend up to 25-30 kilometers under optimal conditions. However, as the distance increases, the likelihood of voltage drops and power losses also rises, necessitating careful planning of substation locations.

In Chhatrapati Sambhaji Nagar, several substations, such as 132kV Satara and 132kV Harsool, have command areas extending over 12-15 kilometers, covering both urban and rural load centers.

Studies by Zhang et al. (2018) suggest that integrating new substations at strategic locations and creating ring networks can effectively optimize the command area radius of existing substations. This aligns with the current proposal to form a 132kV ring network in Chhatrapati Sambhaji Nagar, which will not only reduce the distance between substations but also allow for better load balancing across the network.

2.4 Substation Upgrades and Their Strategic Importance

The need for upgrading existing substations and adding new ones in high-demand regions has been well-documented in the literature. Research by Bhuiyan et al. (2016) emphasizes the importance of upgrading substations in areas with projected industrial growth to meet future power demand.

The findings by Subramaniam et al. (2020), who highlight that upgrading to higher voltage levels and creating additional power sources can greatly enhance system stability and resilience.

The proposed network upgrades for Chhatrapati Sambhaji Nagar, including the formation of a 132kV ring network, substation upgrades, and the realignment of feeders, align with these principles. These changes are critical for addressing the growing power demands of the region and ensuring long-term sustainability and operational efficiency of the transmission system.

III. SYSTEM DEVELOPMENT

The system development process for this study involved a thorough analysis of the existing transmission network in Chhatrapati Sambhaji Nagar, focusing on the 132kV and 220kV substations and their respective feeders. The data collection process and network mapping were conducted to provide a foundation for understanding the current system’s limitations and formulating a proposal for an enhanced transmission network. This section outlines the existing network structure, the load patterns at key substations, and the tools used for data collection, including geographical mapping from MSEDCL (Maharashtra State Electricity Distribution Company Limited).

3.1 Existing Transmission Network and Diagram

The existing transmission network in Chhatrapati Sambhaji Nagar is composed of a series of 132kV and 220kV substations connected through radial and looped feeders. The most critical substations include 220kV Shendra, 132kV Satara, 132kV Waluj, and 132kV Chikalthana. These substations serve both industrial and urban load centers through a network of 11kV and 33kV feeders.

The Figure 1 below represents the existing network structure, illustrating the key substations and the feeders that connect to various load centers. This network supplies power to both urban and rural areas, with a mix of residential, commercial, and industrial loads.

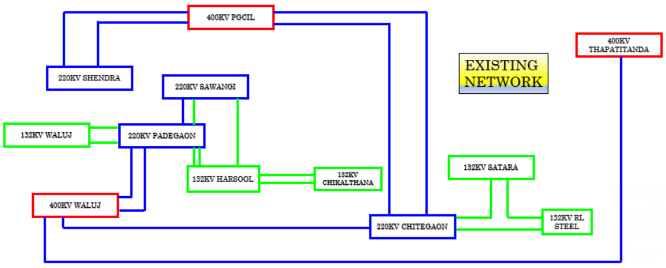

Figure 1: Existing Transmission Network in Chhatrapati Sambhaji Nagar

The network diagram shows radial configurations in many locations, particularly at substations like 220kV Shendra, 132kV Satara, and 132kV Waluj, which are single-source fed, increasing the risk of outages during faults or maintenance. The absence of alternative power sources or backup lines in many parts of the network contributes to reduced reliability.

3.2 Loading Patterns of Substations and Feeders

A detailed loading analysis was carried out for all major substations and their associated feeders. This analysis is crucial for understanding the current load distribution and identifying areas where overloading or underutilization may be occurring. Table 2 below outlines the present capacity and maximum loading of key substations in the region.

Table 1: Existing Loading Patterns of Key Substations

Sr. No.	Name of the Sub-station	Present Capacity	Present Max. Loading
1	132kV Chikalthana Sub-station	175 MVA	100MW
2	132kV Satara Substations	150 MVA	78 MW
3	132kV Harsool Sub-station	200 MVA	85 MW
4	132kV Waluj Sub-station	200 MVA	150 MW

The loading pattern shows that several substations, such as 132kV Waluj and 220kV Shendra, are operating near their maximum capacity. This situation is particularly critical at the Shendra substation, where industrial load from the Shendra MIDC, including large-scale industries like Toyota and JSW, is concentrated. Feeders emanating from these substations, particularly at 33kV and 11kV levels, are also heavily loaded, with some rural feeders extending over long distances, leading to power losses and voltage drops.

The 33kV feeders from 132kV Satara and 132kV Waluj are stretched to serve distant rural and industrial loads, increasing transmission losses and reducing efficiency. Key feeders like 33kV Chittepimpalgaon (20MW) from 220kV Shendra and 33kV Mhada (21MW) from 132kV Chikalthana show significant loading, with further load growth anticipated in the coming years.

3.3 Data Collection from MSEDCL

The data for this analysis was collected from various MSETCL and MSEDCL sources. Key data points include:

- **Loading Data**: Maximum loading figures for each substation and the feeders they serve were collected from the MSETCL load dispatch center and cross-verified with MSEDCL distribution figures.
- **Feeder Network Mapping**: Detailed feeder maps were sourced from MSEDCL, showing the geographical layout of 11kV and 33kV feeders across the district. This mapping helped in understanding the spatial distribution of load centers and the distance between substations and end consumers.
- **Substation-to-Substation Connectivity**:Information on inter-substation connections, including the existing 220kV and 132kV lines, was compiled to assess the redundancy and reliability of the current network.

The collection map (Figure 2) shows the distribution network connecting key substations to urban, industrial, and rural areas. This map was critical in identifying areas where the command area radius of substations, particularly 132kV Satara and 132kV Harsool, was exceeding optimal limits, leading to voltage drops and higher losses in the system.

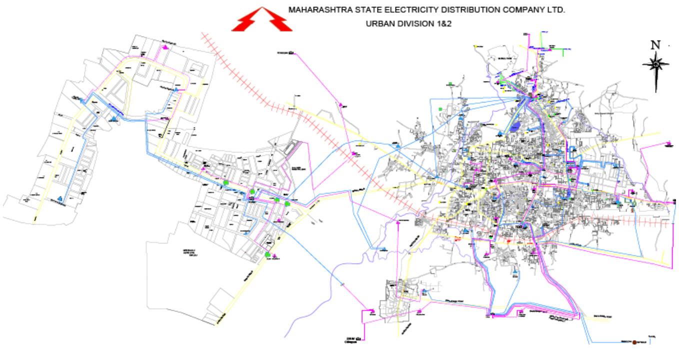

Figure 2: Substation and Feeder Map for MSEDCL Chhatrapati Sambhaji Nagar

The data collected from MSETCL and MSEDCL provided a comprehensive understanding of the current state of the transmission network in Chhatrapati Sambhaji Nagar. Key findings from the analysis include:

- Several substations are nearing their maximum capacity, particularly in industrial areas such as Shendra and Waluj.
- The radial nature of many substations increases the risk of outages and reduces system reliability.
- The distance between substations and load centers, especially for 33kV and 11kV feeders, is leading to significant transmission losses and voltage drops.
- There is a need for additional substations and feeder realignment to accommodate future load growth, particularly in industrial zones like DMIC Bidkin.

This data serves as the foundation for the development of the proposed network enhancements. The goal is to create a more reliable, efficient, and future-proof transmission network by introducing new substations, forming a 132kV ring network, and optimizing feeder arrangements. The next section outlines the proposed upgrades and strategic solutions to the issues identified in this analysis.

3.4 Load Flow Studies using SIEMENS PSSE Software

To accurately model the existing network and evaluate its performance under current and future load conditions, the collected data was modeled and simulated using SIEMENS PSSE (Power System Simulator for Engineering) software. PSSE is widely used in the power industry for conducting load flow studies, which are essential for assessing voltage stability, power losses, and system reliability.

The load flow analysis in PSSE allowed us to:

- Analyze Voltage Profiles: Identify voltage drops at key substations, particularly those located at the extremities of the radial feeders.
- Evaluate System Losses: Quantify the active and reactive power losses in the network, particularly on long-distance 33kV feeders.
- Assess Load Distribution: Understand the current load distribution across the substations and feeders, and how the network performs under peak load conditions.
- Propose Network Enhancements: Based on the simulation results, propose network upgrades such as new substations, feeder realignments, and the formation of a 132kV ring network to improve system performance.

The load flow studies showed that the current configuration, especially in areas served by radial feeders from 132kV Satara and 220kV Shendra, is prone to voltage instability and significant power losses. Moreover, the long distances between load centers and substations increase the likelihood of voltage drops and reduce the overall efficiency of the network.

IV. PERFORMANCE ANALYSIS

The performance analysis of the Chhatrapati Sambhaji Nagar transmission network was conducted using SIEMENS PSSE load flow studies to evaluate the effectiveness of the existing system and to justify the proposed network upgrades. The analysis focused on voltage stability, load distribution, system losses, and performance under contingency scenarios. This section details the findings from the load flow studies, which support the need for new substations and justify the elimination of unnecessary substations within the city area, all while maintaining system reliability and adhering to loading and voltage limits.

4.1 Load Flow Study Results

The load flow studies using SIEMENS PSSE were performed under current peak load conditions and for projected future load growth, including both industrial and residential demands. The primary objectives were to:

- **Evaluate Voltage Stability**: Analyze voltage levels across all substations, particularly at critical points in the network, to ensure that they remain within acceptable limits (typically ±5% of nominal voltage).
- **Assess Power Losses**: Quantify the active and reactive power losses across the system, with a focus on long 33kV and 11kV feeders serving rural and industrial loads.
- **Examine Load Distribution**: Investigate the load distribution across substations, identifying areas of overloading and underutilization.
- **Contingency Analysis**: Simulate potential system contingencies, such as transformer failures or line outages, to assess system resilience.

The analysis shows the voltage levels at key substations after load flow analysis were found to remain within acceptable limits, except for certain areas served by long 33kV feeders from 132kV Satara and 220kV Shendra, which showed signs of voltage drops during peak loads.

- 132kV Satara and 132kV Waluj showed significant voltage drops along 33kV rural feeders, with voltage levels dipping to 95% of nominal during peak load conditions. This confirms the need for additional substations to offload these heavily stressed feeders.
- 220kV Shendra was found to be heavily loaded, particularly with industrial demands from the MIDC Shendra area. Voltage stability was compromised under peak conditions, justifying the need for an alternative power source from the proposed 220kV Karmad substation to reduce the load on Shendra.

4.2 Justification for Proposed New Substations

The load flow studies support the creation of new substations to alleviate the load on existing facilities and improve voltage profiles. Below is a summary of the new substations proposed and their justifications based on the PSSE analysis:

220kV Gandheli Substation:

Currently, the 220kV Shendra and 132kV Chikalthana substations are heavily loaded, primarily serving industrial loads from the Shendra MIDC and the urban area surrounding Chikalthana. The load flow studies showed that the maximum loading at 220kV Shendra is close to 200 MW, while 132kV Chikalthana is operating at 100 MW, with limited capacity for future load growth.

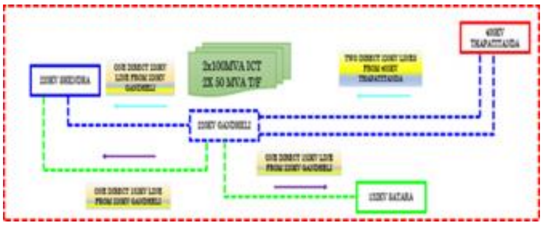

Figure 3 : Proposed 220kV Gandheli Sub-Station

The 220kV Gandheli substation would provide an alternative power source to relieve both Shendra and Chikalthana, particularly for the upcoming load growth in areas like Adul and Deolai. This substation is also crucial for feeding the rapidly developing area near Jalna Road, Beed Bypass, and the airport region.

The 220kV Gandheli substation plays a pivotal role in forming the 132kV ring network for Chhatrapati Sambhaji Nagar. The load flow analysis identified that substations like 132kV Satara and 132kV Waluj are operating in a radial configuration, which leaves them vulnerable to outages and limits load-sharing flexibility. Gandheli would be connected to 132kV Satara, 132kV Harsool, and 220kV Shendra, forming an integrated network that improves power distribution flexibility and enhances system reliability under contingency scenarios.

The industrial expansion along the Paithan Road, especially with the Delhi Mumbai Industrial Corridor (DMIC) project at Bidkin, necessitates additional transmission infrastructure. Load flow simulations forecast significant load increases in this area, with industries such as Toyota, JSW, and Lubrizol expected to require up to 80 MW each. The 220kV Gandheli substation is strategically located to serve these industrial areas without overloading existing substations like Shendra and Chikalthana.

The Gandheli substation will serve as an alternative source of power in the event of transformer failures or line faults at nearby substations. The load flow studies revealed that during a contingency scenario, such as a transformer outage at 220kV Shendra, Gandheli could seamlessly take over the load without violating voltage or capacity limits, thereby ensuring uninterrupted power supply to critical industrial loads and urban areas.

220kV Karmad Substation:

The 220kV Shendra substation is currently tasked with feeding both industrial loads in the MIDC Shendra area and rural loads such as 33kV Gadejalgaon (13.37 MW) and 33kV Bhambarda (13.20 MW). This dual responsibility places significant strain on the substation, limiting its capacity to serve the growing industrial demands from the Shendra MIDC. By diverting the rural load to the proposed 220kV Karmad substation, Shendra would be able to cater exclusively to industrial loads and fast-growing urban areas, while the rural feeders would benefit from a closer and more reliable power source.

The proposed 220kV Karmad substation is strategically positioned to cater to the upcoming load outside the Delhi Mumbai Industrial Corridor (DMIC), extending all the way to Badnapur Taluka. This area is experiencing rapid industrialization, including the development of a new facility for crushing 15+ years scrap cars, covering over 400 acres between Shendra and Badnapur. This new facility, along with other future industrial developments, requires a reliable and scalable power supply, which the 220kV Karmad substation can provide.

The Karmad substation will benefit from a 220kV LILO (Line-In-Line-Out) of the 220kV PGCIL Shendra line. This will offer an alternate 220kV source to the Karmad substation, further reducing the load on 220kV Shendra. By tapping into the existing 220kV line, the Karmad substation will provide improved power flow flexibility and enhance the overall reliability of the transmission network

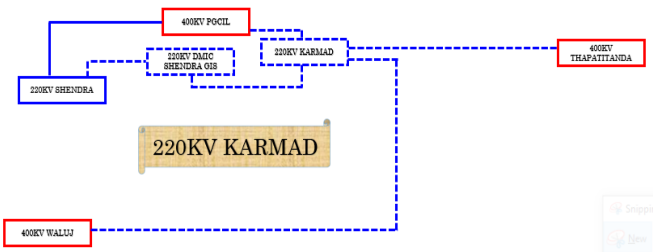

Figure 4 : Proposed 220kV Karmad Sub-Station

The 400kV Thaptitanda substation is identified as a primary source for strengthening the 220kV network across the district. The 220kV Karmad substation will act as a downstream beneficiary of this arrangement, receiving power from Thaptitanda and creating a robust and reliable secondary source for the 220kV Shendra substation. This will significantly enhance the operational flexibility of the network by providing a second 220kV source for the Shendra GIS substation, mitigating the risks associated with single-source dependency

Currently, the 220kV Shendra substation is fully dependent on the 400kV PGCIL network, which has two 315 MVA ICTs at the 765/400/220kV PGCIL Chittepimpalgaon substation. This creates a potential bottleneck and a single point of failure for the region’s power supply. By establishing the 220kV Karmad substation and connecting it to alternative power sources, the network will become more resilient, reducing dependency on PGCIL's infrastructure. The load flow study showed that during peak demand periods, the proposed Karmad substation would significantly reduce the stress on the Shendra substation, ensuring a more reliable power supply for both industrial and rural loads.

220kV Dahegaon Bangla Substation:

The Discom has specifically requested the establishment of the Dahegaon Bangla substation to cater to the growing industrial load along the Ahmednagar Road. The region is experiencing significant industrial expansion, with increasing demands from both existing and new industrial units. The current transmission infrastructure in the area, particularly 132kV Waluj and 400kV Waluj, is operating close to capacity. Establishing a new 220/33kV Dahegaon Bangla substation will help in managing these increasing loads, ensuring a more reliable and stable power supply.

The load flow study identified significant loading on both 400kV Waluj and 132kV Waluj substations, with major feeders such as 33kV Limbejalgaon (25 MW), 33kV Ceat (18 MW), and 33kV Veer Gujar (11 MW). The 220kV Dahegaon Bangla substation will help divert industrial and rural loads from these overburdened substations, allowing them to focus on more localized urban and industrial loads. By offloading these feeders, the overall efficiency and voltage stability of the network will improve, reducing the risk of overloads and outages during peak demand.

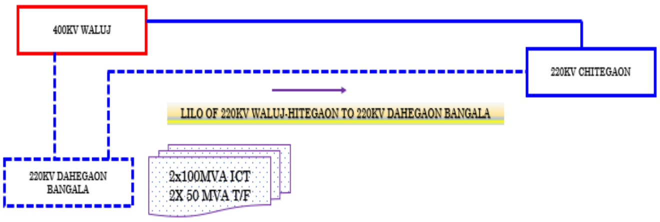

Figure 5: Proposed 220kV Dahegaon Bangla Sub-Station

One of the key benefits of the Dahegaon Bangla substation is the cancellation of the requirement for a 132/33kV 50MVA transformer at 132kV Gangapur. The load flow studies showed that 132kV Gangapur is currently serving both industrial and rural loads, with feeders such as 33kV Shendurwada (14 MW) and 33kV Veer Gujar (11 MW) nearing capacity. By diverting these loads to the proposed Dahegaon Bangla substation, the need for additional transformer capacity at Gangapur can be avoided, saving significant capital costs while maintaining system reliability.

The load flow analysis also identified significant space constraints at 132kV Waluj, which has been requested by the Discom to accommodate two new 33kV bays. However, due to the lack of available space for new feeders, the 220/33kV Dahegaon Bangla substation provides a practical solution.

By shifting one of the heavily loaded 33kV feeders, such as the 33kV Ceat bay, from 132kV Waluj to 220kV Dahegaon Bangla, the space limitations at Waluj are resolved without compromising load-serving capacity

Furthermore, its connection to 400kV Thaptitanda will enhance the stability and reliability of the 220kV network across the district, making it a vital part of the transmission network upgrade for Chhatrapati Sambhaji Nagar.

400kV Bidkin Substation (Upgraded from 220kV):

The upgradation of the 220 kV DMIC Bidkin substation to a 400 kV substation is essential for multiple technical, strategic, and economic reasons. Based on the current analysis, here is a detailed justification:

The Bidkin DMIC area is expected to witness exponential industrial growth with significant power demands. Notable companies like Toyota (80 MW at 220 kV), Ather (40 MW at 132 kV), JSW (80 MW at 220 kV), and Lubrizol (25 MW) are expected to establish operations in the area. To ensure uninterrupted and reliable power supply, the existing 220 kV substation will be insufficient, necessitating an upgrade to 400 kV.

Currently, the 220 kV Shendra substation is fully dependent on the 400 kV PGCIL Chittepimpalgaon substation. This dependency creates a significant risk of a single point of failure, which could lead to widespread outages in the Shendra region. Additionally, power flow studies suggest that further loading on the PGCIL network will increase instability, especially as power demands shift from the 132 kV Chikalthana to Shendra. A new 400 kV substation at Bidkin would provide an alternative, more stable power source and reduce the load on the existing infrastructure.

Establishing a 400 kV substation at Bidkin has strategic advantages, as:

- The 400 kV Thapatitanda substation has two available bays and is geographically near Bidkin, simplifying the installation of new transmission lines.
- Ample space for future expansion at Thapatitanda, including the potential to add an additional 500 MVA ICT, will further enhance the power grid for industrial and urban loads in the region.
- Direct 400 kV lines from Thapatitanda to Bidkin will bolster grid reliability and strengthen the network, ensuring smoother transmission with less risk of overloading any single line or source.

The upgradation from 220 kV to 400 kV will not only meet the immediate industrial power requirements but also accommodate future growth. The DMIC Bidkin area is expected to grow with more industrial and urban developments along the Paithan Road, and new residential and commercial projects are emerging. With the upgradation to 400 kV, additional transmission lines and substations can be created, enhancing the overall resilience of the network.

The current power infrastructure relies heavily on the PGCIL Chittepimpalgaon substation, which creates multiple points of risk, including the potential shutdown of circuits. Over the last two years, the 220 kV Chitegaon Circuit was shut down 14 times. Exceeding the 20000 MW drawal limit from PGCIL could force them to limit access to power from critical substations, reducing reliability. A 400 kV Bidkin substation would reduce dependency on PGCIL, securing MSETCL’s autonomy over power distribution in the region and preventing potential loss of business to PGCIL.

If the 400 kV substation is not established, PGCIL could potentially build a 400 kV substation nearby due to the proximity of the 765/400 kV PGCIL Chittepimpalgaon substation. This would allow PGCIL to capture more industrial loads and deprive MSETCL of revenue and market share. Upgrading the Bidkin substation to 400 kV strengthens MSETCL’s position in the region and ensures that future industrial power demands are met by their infrastructure.

The DMIC Bidkin area is a key region for future industrial growth, with large-scale projects such as car scrap facilities and residential development expected. The Bramhangaon water scheme is also set to increase agricultural loads in the area. Upgrading the Bidkin substation ensures that the power infrastructure is robust enough to handle these diverse demands.

4.3. Elimination of Unnecessary Substations

The load flow studies also revealed that certain substations proposed for the city area were not necessary, given the existing network capacity and projected load growth. These include:

132kV Golwadi Substation: The load flow results indicated that the proposed 132kV Golwadi substation, initially planned to serve the growing residential load, could be eliminated. The voltage levels at 132kV Satara and 132kV Waluj were found to be stable, and the anticipated residential load growth could be accommodated by the creation of a 33kV level at 220kV Padegaon. This modification releases the load from 132kV Harsool and 132kV Satara, negating the need for a separate Golwadi substation..

132kV Karodi Substation: Similarly, the proposed 132kV Karodi substation was deemed unnecessary based on the load flow studies. The results showed that the creation of 33kV feeders from 220kV Padegaon could handle the load from the Karodi area without violating voltage or capacity limits. This adjustment optimizes the use of existing substations, eliminating the need for new infrastructure and reducing capital costs.

After redistributing loads and eliminating unnecessary substations, the voltage profiles and load distribution across the network improved significantly, as shown in Figure 4. The formation of the proposed 132kV ring network and the addition of new substations like 220kV Karmad and Dahegaon Bangla reduced feeder distances and improved system resilience.

Contingency analysis was performed to evaluate the system's resilience under failure scenarios, such as transformer outages or line faults. The PSSE simulations revealed that:

The 132kV ring network proposed for the urban area would significantly improve the network's redundancy, allowing power to be rerouted during faults. The load flow studies demonstrated that during a transformer outage at 132kV Satara, the load could be seamlessly shifted to 132kV Harsool and 132kV Chikalthana, without violating voltage limits(STU Write-up).

The 220kV Karmad substation provided critical backup support for 220kV Shendra in contingency scenarios, preventing overloading of the remaining feeders and maintaining voltage stability. This substation also helped in redistributing load during scheduled maintenance at 400kV Thaptitanda..

Based on the analysis the network of the Chhatrapati Sambhaji Nagar is proposed as per the below mentioned figure.

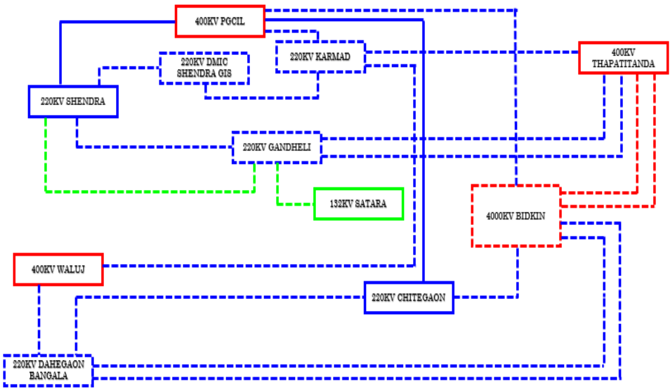

Figure 2: Proposed Netwok of Chatrapati Sambhaji Ngar Area

The contingency analysis confirmed that the proposed network enhancements would significantly improve system resilience during outages or faults, ensuring a stable and reliable power supply for Chhatrapati Sambhaji Nagar's future growth.

V. CONCLUSIONS

This paper has provided a detailed analysis of the existing 132kV and 220kV transmission networks in Chhatrapati Sambhaji Nagar and identified key challenges related to load capacity, transmission losses, and system reliability. Through load flow studies using SIEMENS PSSE software, the study has shown that substations like 132kV Satara and 220kV Shendra are heavily loaded, with significant voltage drops and high transmission losses in rural feeders. The formation of a 132kV ring network and the addition of new substations such as 220kV Gandheli, 220kV Karmad, and 400kV Bidkin have been proposed as solutions to improve system resilience, reduce voltage instability, and accommodate future industrial and urban growth. The elimination of unnecessary substations further optimizes the network, reducing capital expenditure while maintaining reliable power distribution. The proposed upgrades ensure that Chhatrapati Sambhaji Nagar's power infrastructure is equipped to meet the increasing demands of industrial and residential developments, particularly in the context of the Delhi Mumbai Industrial Corridor (DMIC).

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