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Structural analysis of power grid network and its nodal accessibility on the spatial disparities in economic development in the southern districts of West Bengal

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Abstract
Power Grid line is an important hard infrastructure and this contributes in stepping up towards economic development of any region. West Bengal also has well-knit power grid network. The power voltage used for commercial purposes in West Bengal ranges from 400 to 132 KV and this is called Power Transmission Line. There are districtwise disparities in the distribution of this network. This distributional bias is reflected through the network connectivity and nodal accessibility in different districts of West Bengal. The intra-district network connectivity has positive impact on the economic development. There is also unequal and imbalanced distribution of transmission lines in overall the state itself. Some nodes are getting priority on the basis of the degree of nodes on direct connectivity. Besides there is another important factor on the basis of the degree of interaction among different power grid lines i.e. Efficiency of power transmission is another important issue in economic development. The disparities in these entire network related issues are conspicuous in West Bengal. West Bengal is still lagging behind in the approach towards utilization of power in the commercial sector. The industrial regions in West Bengal also face different power related problems like inefficient power transmission, lacunae in network coverage, paucity of road lightening in the industrial belts etc. So an approach related to balanced distribution of network connectivity, accessibility, degree of nodes, efficient power transmission, un-interrupted power supply should be adopted in all over the districts. These will lead towards stable, continuous and balanced power transmission in near future.

Keywords: Network connectivity, distributional bias, power transmission lines, degree of nodes, degree of interaction, power consumption

1. Introduction
West Bengal has been considered as the pioneering State in power development over years. According to National Association for Software and Services Companies-Gartner (NASSCOM-Gartner), West Bengal has the best power infrastructure (Bhandari and Karan, 2007) [2]. West Bengal has been known as the power surplus State. The major initiatives taken to achieve are continuous, stable and quality power to the consumers. There are lot of power stations running under central, state and private sectors. West Bengal is falling under Eastern Regional power grid which is the largest exporter of power in the country and this regional power grid produces maximum of the surplus power.
West Bengal has widespread distribution of power grid network transmission and distribution lines. The transmission network lines are of 400, 220 and 132 KV lines. These grid lines are used for commercial purposes and hence these power grid lines are called Commercial power grid lines.

2. Objectives
(i) To illustrate the intra and inter district disparities in the power grid network connectivity in the southern parts of West Bengal.
(ii) To focus on the major issues regarding power grid network connectivity and accessibility which are responsible behind the nodal disparities.
(iii) To evaluate the importance of power grid network connectivity and accessibility on the overall regional economic development in the concerned study area.

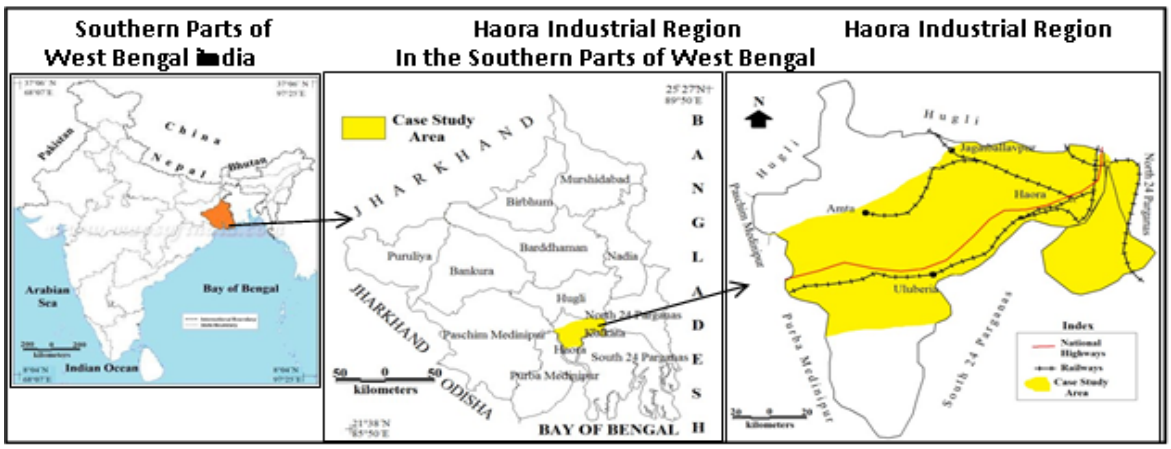
(iv) To identify the major problems, to record observations and to put forward some suggestions regarding power grid network connectivity, accessibility and related services.

3. Materials and Methods

The overall study consisted of review of literature on the related topic as well as data collection from different secondary sources like West Bengal State Electricity Distribution Limited (WBSEDCL), Central Electricity Authority (CEA) and West Bengal State Electricity Transmission Limited (WBSETCL) and different reports like Census of India, State and District Domestic Product, Economic Review of West Bengal, District Statistical Handbooks etc. Primary level of study was conducted on the industrial personnel in the Haora-industrial region on the basis of the suitable sample size and purposive sampling techniques. The perception study on the availability of power and related constraints were conducted on the basis of the questionnaire-based survey. The collected data were computed with some network analysis techniques like Aggregate
Transportation Score, Shimbel's (1953) shortest path matrix of nodal accessibility. Economic development score was computed with the help of Kendall's composite score of development. Besides, some cartographic techniques were also applied for analysis of data. Final shape of the works was given through the maps, diagrams and major findings.

4. Location of the Study Area

The southern parts of West Bengal (21°38´N to 25°27´N and 85°50´E to 89°50´E) surrounded by Jharkhand and Odisha on the western margin, Bangladesh on its eastern side, Bay of Bengal at the southernmost margin and Malda district of the same State on the northern part was selected for the study with secondary data bases. This region shows wide disparities in power grid network. Besides, Haora industrial region was selected for the study based on primary data followed by case specific analysis.

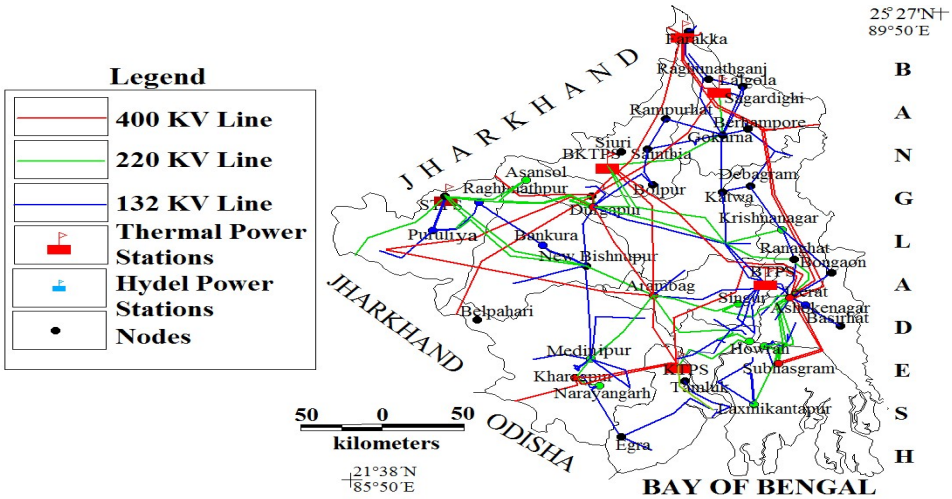


Source: NATMO 2011

Fig 1: Location of the Area under Study

5. Scenario of Power in West Bengal

Power Scenario in West Bengal has evolved out of development of power grid lines in the major industrial and urban centers to extension of transmission and distribution grid lines at the remote and interior areas. Different power stations are running under three different sectors: central, state and private sectors.



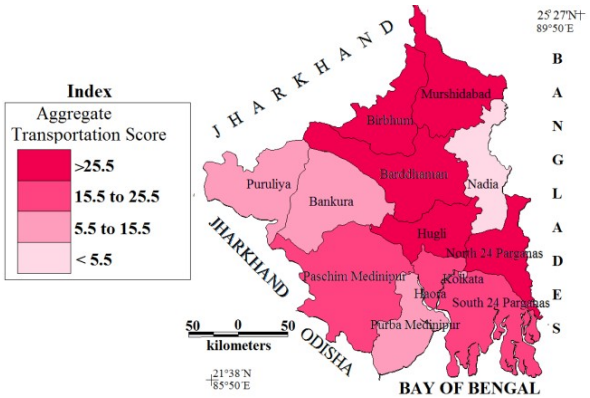
Source: Computed from the data procured from WBSEDCL, Govt. of West Bengal and Power Grid Corporation of India Limited, 2016 West Bengal has maximum share of allocation of power between central and state sectors.

Fig 2: Spatial Distribution of the Commercial Power Grid Lines in the southern Parts of West Bengal, 2016

The major power generating stations which are actively operating are DVC, NTPC and NHPC under the central sector, DPL, WBPDCL and WBSEB under the surveillance of the State sector while CESC, Dishergarh and Sunderban etc. are running under the auspices of the private sector (West Bengal Power Department, 2016). Other sectors of power generation except WBSEB show increasing trend in generation of power. WBSEB was fragmented into WBPDCL, WBSEDCL and WBSETCL in 2002. So, all the units were shifted to those above mentioned three parts. As a result WBSEB showed decreasing trend of power generation. Major power stations running in the southern parts of West Bengal are Farakka, Sagardighi, Bakreshwar, Bandel, Kolaghat and Santaldih thermal power stations.

Power transmission grid lines show 400 to 132 KV lines.

Barddhaman district has the maximum length of coverage of power grid transmission lines in the southern parts of West Bengal (Fig: 2). Murshidabad, Nadia and North 24 Parganas districts on the left bank of the river Hugli and Birbhum, Barddhaman, Bankura, Hugli, Purulia and Paschim Medinipur districts on the right bank of the same river have considerable lengths of 400 KV lines.



Source: Computed from the data provided by WBSEDCL, Govt. of west Bengal

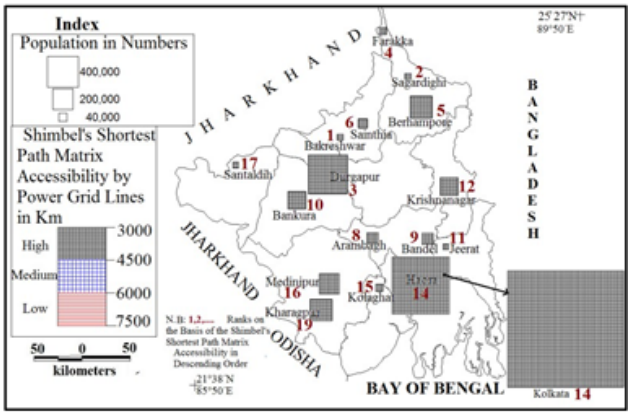
Fig 3: Connectivity of Power Grid Transmission Network, 2015

6. Network Analysis of Power Grid Transmission Lines

Network is defined as "a set of geographic locations interconnected in a system by a number of routes" (Kansky, 1963) [6]. Network has mainly two structural properties: firstly,

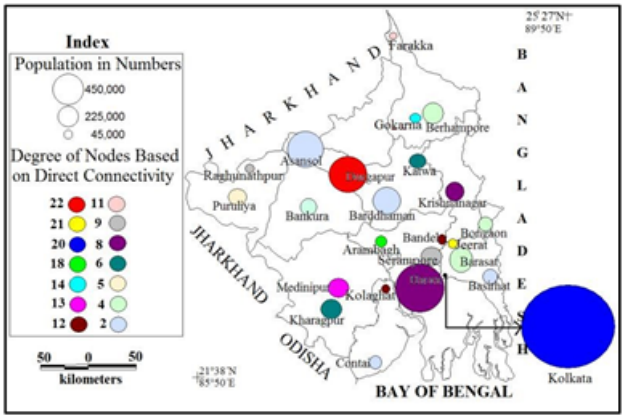
the overall character of the geometrical pattern which is known as the Network connectivity and secondly, characteristics of the individual element in the whole of the network which is known as the Nodal accessibility. Aggregate Transportation Score which is computed through the summation of Alpha, Beta, Gamma index and Cyclomatic number, was applied on the power grid network map (Fig: 3). This figure illustrates the fact that Murshidabad, Birbhum, Barddhaman, Hugli and North 24 Parganas districts in the study area have the most complicated power grid network connectivity. Murshidabad has two major thermal power plants: Farakka and Sagardighi. In the overall intra-district network connectivity pattern visible within the district, Murshidabad is very much widespread. Birbhum district experiences the profound effect of Bakreshwar thermal power station in the overall power grid network connectivity.

The overall inter-district Nodal accessibility map (Fig: 4), computed on the basis of the Shimbel's shortest path matrix accessibility, shows that almost all the nodes in southern part of West Bengal are situated at the highest accessibility position on power grid network. Among those different centers, Bakreshwar, Sagardighi and Durgapur have the most accessible locations on power grid transmission lines. A reference of population size has also been depicted on the map. It was done simply to emphasize on the importance of the nodes. Kolkata and Haora although being two major centers of population are located not at very much accessible positions on the power grid lines.



Source: Computed from the data provided from WBSEDCL, Govt. of West Bengal

Fig 4: Nodal Accessibility of the Power Grid Network, 2015



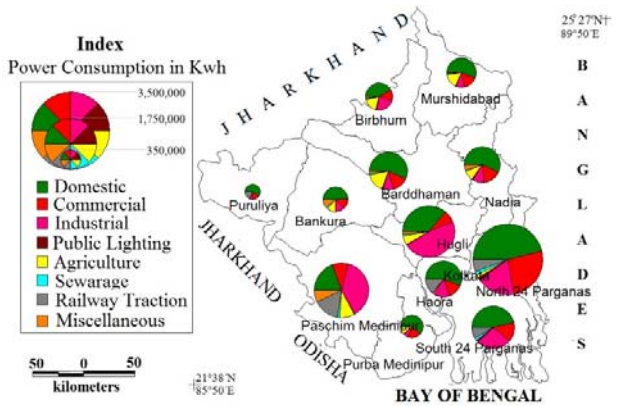
Source: Computed from the data procured from WBSEDCL, Govt. of West Bengal

Fig 5: Degree of Nodes based on Direct Connectivity of the Power Grid Network Lines, 2015

Fig: 5 depicts the degree of nodes of different power grid transmission centers which were measured on the basis of the direct connectivity. Durgapur, Jeerat and Kolkata: these are the centers having the most important and maximum viability on the basis of the power grid transmission line junctions. Here lies the nodal importance, not the regional or spatial importance. The reference of population size was also used to indicate the nodes' urban influence. For example, Jeerat, Gokarna, Bakreshwar, Bandel and Farakka have no urban influence. Still these nodes have dominance on the degree of power grid lines. Conversely, Haora although having metropolitan influence has not recorded satisfactory degree of transmission lines.

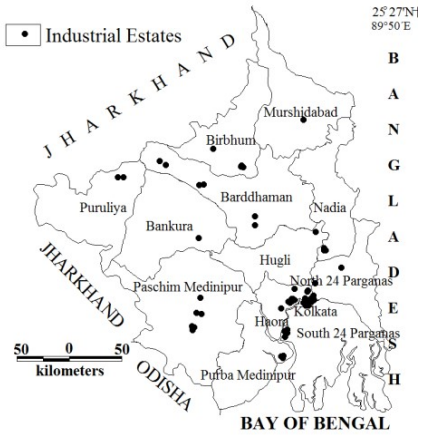
7. Power Consumption Scenario

West Bengal is still lagging behind in terms of total installed capacities of Thermal and Renewable power sources in comparison to other industrially developed states like Maharashtra, Gujarat, Tamil Nadu, Andhra Pradesh and



Source: District Statistical Handbook, B.A.E.S

Fig 6: Sector-wise power Consumption Scenario, 2015



Source: Brief Industrial

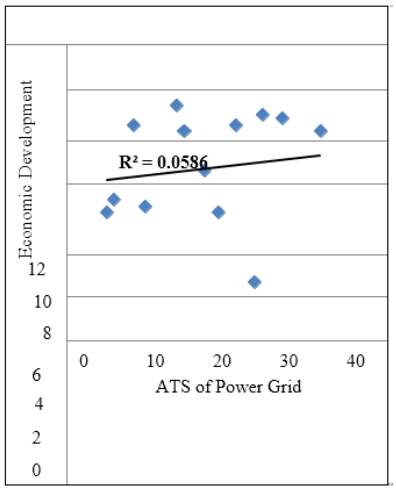
Fig 7: Industrial Estates, 2015

Karnataka etc. It is very interesting that overall the districts in southern part of West Bengal have almost similar scenario in terms of power consumption (Fig: 6). West Bengal has recorded maximum share of power consumption at the domestic sector. This is good in terms of domestic power supply position. With the growth of village electrification programmes, domestic power grid lines i.e. ≤ 66 KV line have developed to some extent. But the same scenario is not viable regarding industrialization or commercial demand for power in any State. On the present day still in general the districts in West Bengal share a meager amount of power consumption at the industrial and commercial sectors. However, the situation is quite progressive and hopeful in the cases of Hugli and Paschim Medinipur districts. So the power grid transmission lines are still underused in the industrial sector.

Govt. of West Bengal Profile of the Districts, Ministry of MSME, Govt. of India

8. Power Grid Lines having Effect on the Industrial and Economic Development: Although West Bengal has a comfortable position in generation of electricity, transmission and distribution networks should be geared up for industrial development (Raychaudhuri and Das, 2005) [7]. A transmission system project was also taken up with the assistance of Japan Bank for International Cooperation (JBIC Team). Besides, power supply in urban and industrial sectors suffered in consequence of heavy drawal of power in the countryside causing load shedding once upon a time. So the towns and industries experienced periodic power cuts which became endemic during that period (Sen and Dasgupta, 2007) [9]. Causes behind crises at the power sector are very much diversified like use of obsolete machines, labour unrest, lack of skilled personnel in power projects, too much time taken by the ongoing projects for completion of the plants, transmission loss etc. (Basu, 1989) [1]. Need for increasing the power generation capacity of the State was emphasized through extension of transmission network. Major contribution of the power grid transmission lines towards industrial and economic development has been analyzed under following heads:

i. Economic Development: Economic development computed on the bases of different parameters like Net District Domestic Product (NDDP), Per capita income, number of Micro, Small and Medium Scale Enterprises (MSMEs), Work Participation Rates and decadal growth rates of the Census and Municipal towns (2001-11) shows positive correlation with Aggregate Transportation Score (ATS) of the commercial power grid lines (Fig: 8). The intra district connectivity of the power grid network lines is positively related with the level of economic development. Proper utilization and adequate production of electricity are conducive for creation of more employment in different sectors. It gives the people security in earning livelihood and improving standard of living (Roy, 1993) [8]. The positivity of the relationship between these two variables may be enhanced through optimization of power grid lines in the economic sectors.



Data Sources: 1. WBSEDCL, Govt. of West Bengal
2. State and District Domestic Product, Govt. of West Bengal
3. Census of India, 2001-11
4. District Development Reports, Govt. of West Bengal
5. Brief Industrial Profile of the Districts, Ministry of MSME, Govt. of India

Fig 8: Correlation between Connectivity Indices of Power Grid Network and Economic Development

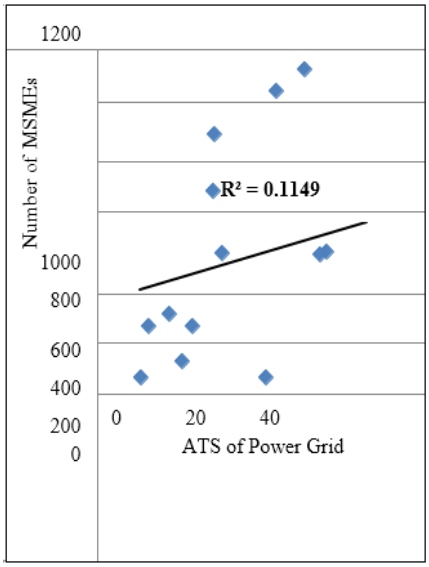
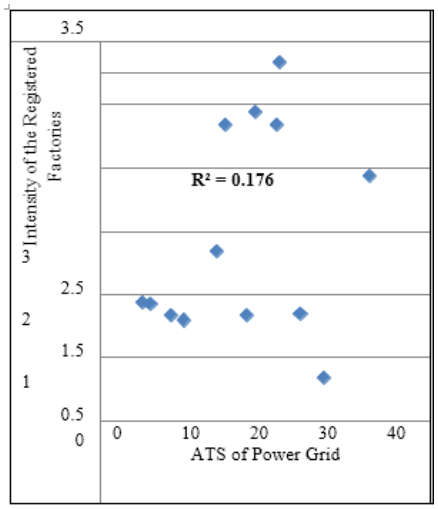


Fig 9: Correlations between Connectivity Indices of Power Grid Network and Micro-Small-Medium Scale Units

ii. Number of Micro, Small and Medium Scale Enterprises (MSMEs): Availability of power and power grid lines is also necessary for the Micro, Small and Medium Scale industrial units. Barddhaman, Haora, North 24 Parganas and Paschim Medinipur districts have maximum concentration of MSMEs. In view of the importance of power for industrial development and agricultural modernization, the outlay on power has been substantially increased (Ghose, 1977). Connectivity of intra-district power grid lines is positively related with the number of MSMEs (Fig: 9).

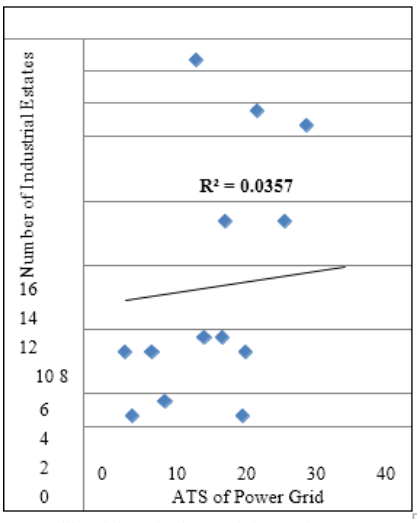
iii. Intensity of the Registered Factories along with the Scope of Employment: Intensity of the registered factories along with the capacity for employment generation is measured through the Intensity Indices. Barddhaman, Haora, North 24 Parganas and Hugli districts have higher agglomeration of the registered factories along with their larger size of employees. Intra-district connectivity of the power grid lines are positively related with intensity of the factories (Fig: 10).

iv. Industrial Estates: There are about 31 MSME commercial estates and 10 industrial estates in West Bengal. Seven new industrial estates have also been set up in different districts of the State. Haora, Barddhaman, Kolkata, North 24 Parganas and Paschim Medinipur districts have maximum allocation of Industrial Estates and urban clusters. Consequently positive relationship was also observed between intra-district connectivity of the power grid lines and the number of Industrial Estates (Fig: 11).



Data Sources: 1. WBSEDCL, Govt. of West Bengal 2. Brief Industrial

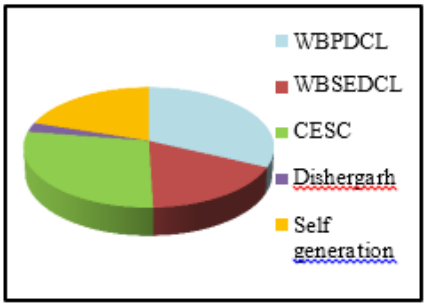
Fig 10: Correlation between Connectivity Indices of the Power Grid Network and Intensity of the Registered Factories

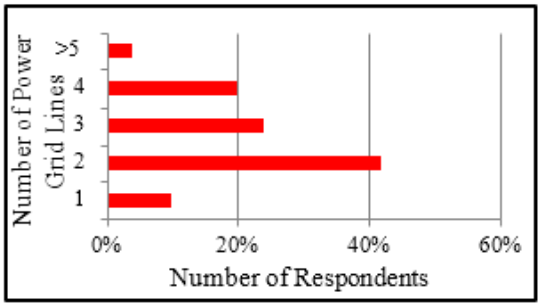


Data Sources: Profile of the Districts, Ministry of MSME, Govt. of India

Fig 11: Correlation between Connectivity Indices of the Power Grid Network and Number of Industrial Estates

9. Case Specific Study of Haora-Industrial Region: Haora Industrial region has well-knit National and State Highways network on one hand as well as Eastern and South-Eastern Railway line on the other. Major power generating units are WBPDCL, WBSEDCL, CESC, Dishergarh and some self-generating plants (Fig: 12). Despite being an industrial region, the connectivity of the power grid lines is not satisfactory (Fig: 13). The factories have the demand of power because most of the factories have six to ten power driven machines (Fig: 14), while excess power transmission to the respective power grid lines are conspicuous in most of the cases (Fig: 15).





Source: Primary Data, 2015

Fig 12: Different Power Generating Sources of Haora Industrial Region **Fig 13:** Power Grid Lines in Haora Industrial Region

Major problems identified regarding power supply position in the Haora industrial sector are:

a. Lack of sufficient power generating stations within the district

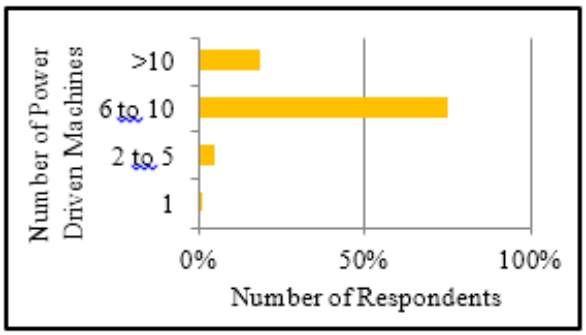
b. Higher dependence on power grid lines and transmission nodes of Kolkata

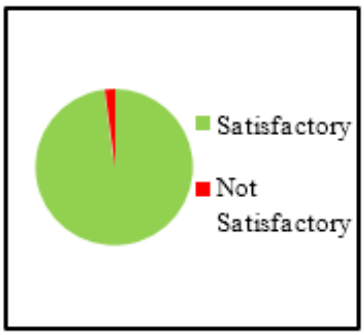
c. In-sufficient power transmission and distribution grid lines in the district

d. High frequency of power failure

e. Restriction imposed on power usage

f. Absence of initiative for power banking system.





Source: Primary Data, 2015

Fig 14: Power Driven Machines in Haora Industrial Region **Fig 15:** Perception of Power Transmission Haora Industrial Region

10. Major Findings: Major findings as derived out of the foregoing discussion have been presented below:

(i). The districts Nadia, Purba Medinipur, Puruliya and Bankura have low level of commercial power grid network connectivity on one hand and imbalance in its distribution within the districts on the other.

(ii). The intersection points of the transmission centers are concentrated around the nodes of Durgapur, Jeerat, Kolkata, Arambagh, Medinipur, Kolaghat and Bandel. In some cases the nodes are neither much developed to cater the requirement of the industries, nor these have major metropolitan influence. Unfavourable location of the power stations is another major determinant behind these spatial and nodal disparities.

(iii). Haora industrial region has poor transmission intersection points and poor power grid lines network coverage in comparison to that of Durgapur industrial region. Still the region has efficiency in power transmission from the different grid lines which is absent in many cases in the major centers of Birbhum and Murshidabad districts. So, not only the factors of transmission lines but the intensity of power transmission also is important issues regarding effective network coverage. Besides, the degree of interaction among different power grid lines is another issue to reckon with.

(iv). Cases of power failure are still frequent at this advanced stage of civilization in the Haora industrial region which is very much painful.

West Bengal shows certain promising signs for better energy situation in the state because of its financially viable power sector, energy surplus situation and its easy accessibility (Energypedia.info, 2016).

11. Suggestions: Some suggestions based on the findings and analyses have been put forward underneath:

(a) Power Grid Transmission Network coverage apart from higher allocation of more high voltage transmission lines exclusively for the industrial region in the Haora industrial belt should be enhanced.

(b) Transmission of power through the transmission lines at the major urban centers in Birbhum, Murshidabad and Nadia districts should be more efficient. Besides, other major residual factors viz. scope of power investment in the development projects, problems of getting available land, modernization of industrial policy etc. should also be taken care of for the sake of industrialization and commercialization.

(c) The power transmission lines should be uniform and balanced spatially in all over the districts coming under the purview of present discussion.

(d) Share of power consumption at the commercial and industrial sectors needs to be enhanced which would

contribute to revamp the local economy in particular and that of West Bengal in general.

(e) No provisions of road lightening are there at the industrial belts in Haora industrial region. This requires adequate attention as a pull factor to invite more investment as well as to tame the anti-social elements.
(f) Scope of power banking system at the industrial sector should be explored.
(g) Provisions for new development projects need to be made regarding usage of the surplus power.
(h) Development of renewable energy as well as its transmission network should be prioritized throughout West Bengal as a part of introducing green technology.
(i) Lastly, it may be stated that through proper management plans like use of modern machineries with the state of the art technology, pacifying labour unrest, reducing the transmission losses, the constraints of the power sector may be addressed properly.

Smart Grid facilitates efficient and reliable end-to-end intelligent two-way delivery system from source to sink through integration of renewable energy sources, smart transmission and distribution. In this way Smart Grid technology shall bring efficiency and sustainability in meeting the growing electricity demand with reliability and best of the quality (Power Grid Corporation of India Limited, 2016).

12. Conclusion

From the above discussions it is concluded that West Bengal has been facing some typical power transmission related problems which are quite different and exclusive. The transmission network lines which are developed from the power generating stations are the most important factors here because the power generating centers are not located at very developed centers. The spatial disparities over the districts in the distribution of transmission networks are there. Besides, nodal disparities in the matter of source regions of grid lines also exist. Again, some of the districts have better transmission network but the function of power transmission is inefficient. That is the major reason behind inefficiency of the overall power grid network lines. Enhancement of the transmission of surplus power at the grid lines in overall the State along with proper utilization of existing power generating stations would be the best way to overcome the power related problems in West Bengal. So, smart grid management and adoption of smart grid technology would boost up the power generation, transmission and usage scenario in West Bengal.

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