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ORIGINAL RESEARCH PAPER

Engineering

OPTIMAL SELECTION OF OVERHEAD VS UNDERGROUND TRANSMISSION LINES TO MITIGATE ENERGY LOSSES

KEY WORDS: energy efficiency, overhead lines, power losses, underground lines

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ABSTRACT

The power transmission and distribution system undergo losses due to many factors. The losses account for 5-7% of the total transmitted power to the end user. This accounts for the losses from the given system itself which adds further to the efficiency of the appliances and equipment connected at user end. It becomes crucial to evaluate the reasons for the losses at transmission and distribution and provide with recommended approach in reducing these. One of the major issues with transmission and distribution is to select optimal paths for the conductors to ensure reduced lengths of travel to the substations and from substations to end customers. Additional considerations from the underlying cause of increased losses from heating and ambient temperature of exposure offer an area to evaluate how underground lines become a viable choice as they operate at significantly lower ambient temperatures than their overhead counterpart during summer days. Regions with more summer days may benefit from underground lines, and those with higher winter days from overhead lines. In varying regions in India, the temperature to which the transmission lines are exposed varies. Some regions experience higher summer days compared to rest. For typical transmission line length and equivalent savings from 1-degree Celsius drop in temperature was projected for all proposed transmission line conversion from overhead to underground and vice versa.

INTRODUCTION:

The transmission and distribution system is major component of electrical power grid systems in the India and around the world [1] [2]. The integrated manner of operation of generation stations with the grid to ensure power supply to the customers with minimal outages in primary goal of grid operation. Typical transmission line voltages are 60kV to 500kW wherein the higher the voltage the lower are the transmission and distribution losses in the system. This is evident from the basic relationship between the power and voltage as shown in equation (1). Clearly higher the voltage at constant power the current will be lower per Ohms law and equation (1) [3].

$$P = \frac{V^2}{R} \quad (1)$$

Transmission lines typically are longer distance runs and may cross countries as well. The conductors are either overhead or underground depending upon the suitability of installation and availability of the spaces. The overhead lines see several stresses from structural integrity of the system such as spans typically have sag due to inherent weight of the conductors. Additionally, environmental factors such as wind, snow, and rain increase the vulnerability of lines to corrosion and physical damages [4]. However, the underground lines experience lesser exposure to these effects from the environment. The advantages of underground lines include less exposure to communication networks and ease of installation under the rivers.

Distribution system is typically lower than 33kV of operating voltage and shorter in lengths compared to the transmission lines. There are majorly wooden poles of shorter heights with pole mounted transformers in the distribution applications. However, transmission line systems have high metal towers and typically a three-phase system. Distribution systems are sometimes single-phase as opposed to a typical three-phase system. Transmission lines lead to substations that step down voltage at multiple levels before feeding the distribution system. The conductors for transmission lines are mainly Aluminum Conductor Steel Reinforced (ASCR) and are labeled or designated by tree names. Measures must be taken to reduce the losses per the results in [5]. Renewable energy usage integration with power grid reduces burden on grid power [6] and thus bolsters the efforts in energy savings from reduced losses from transmission line system through measures as studied in this paper. Use of energy management system [7] at users end further improves the energy efficiencies of the transmission lines as optimized demand results in lesser current drawn in the lines. Figure 1 shows states identified with zones/ regions. For example, n stands for north region.

Available research analyses the benefits of the overhead vs underground lines and vice versa but lacks documentation on impacts of utilizing large scale benefits from conversion of overhead lines to underground system where it is possible to draw inherent benefits from underground lines. This paper is focused around conversion of overhead lines at multiple locations where it can possibly decrease the transmission losses significantly. It is typically seen that Northwest region, Gujarat, Odisha, Maharastra, northern Karnataka, Andhra Pradesh, western Madhya Pradesh, Rajasthan, Tripura, Punjab, Haryana, Delhi, Mumbai, and Kolkata experience high number of summer days than winter.

Figure 1: Zones in India
Sources: https://www.mapsofindia.com/zonal/

Table – 1 Savings

Region	Length of Overhead Lines (km)	Savings with Underground Conversion (TWh)
Northern	244,546	-
Eastern	228,343	1.15
Western	167,961	0.85

Southern	285,844	0.72
Central	242,101	1.22
North East	143,110	0.72

Table – 2 Savings

Region	Length of Underground Lines (km)	Savings with Overhead Conversion (TWh)
Northern	36,682	0.22
Eastern	34,251	-
Western	25,194	-
Southern	42,877	0.13
Central	36,315	-
North East Zone	21,466	-

METHODS:

The average temperature of locations with greater number of summer days and greater number of winter days were documented from the literature and weather updates. Table 1 and Table 2 indicate the regions with respective temperatures during winter and summer. A total length of overhead transmission lines was availed, and their respective conversion was calculated. The energy savings were based on the assumption of copper ASCR conductors with 0.39% improvement per 1-degree Celsius fall in temperature [8]. The total physical length for a three-phase system of transmission lines at varying voltages is 1,543,417 km. An assumption of 85% of lines being overhead and 15% underground was based on a typical profile for transmission lines system for the Delhi region. Each region was assigned total length of conductors as a fraction of the area of the region to the total area of the country. Selection of optimal paths for the transmission lines for the overhead option is limited by several above-ground structures, but with underground lines, these challenges become less challenging. For example, bored electrical ducts underneath the ground surface are viable where above-ground structures may be a limiting factor for overhead installation.

RESULTS:

The savings from the conversion was tabulated in Table 1 and 2. The total energy was taken as 1,949 TWh transmitted (annually) via the existing lengths of transmission lines in Tables 1 and 2. Based on a 1-degree Celsius variation (drop) in temperatures (annually), the overall savings is 0.39% of transmitted power via a given overhead or underground lines when switched their types.

CONCLUSIONS:

A substantial improvement in the efficiencies is seen when conversion is done from overhead to underground and vice versa, depending on the number of summer and winter days in India. Majorly eastern and central regions have significant energy savings from loss reduction from transmission lines. Although the cost of this major change is not accounted for the studies, this moves becomes promising when significant energy savings are possible by just switching between the given types of transmission lines system in India. The selection of optimal paths for the transmission lines becomes a topic for future study. The study was limited around the assumption that there will be no operational challenges with large scale conversion from overhead to underground system. The potential of reduced ambient temperature that transmission lines will be exposed to with proposed changes is dependent on weather conditions that remain similar or contribute in a positive direction for reduction in energy losses.

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