Solar PV Application in Industrial Conveyor System

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ABSTRACT

This research focuses on converting a conventional electromechanical motor into a solar powered electromechanical motor for the application in material handling systems in industries. As conveyors are the prime movers for in handling raw materials from mines covering a major area, an effort has been made in incorporating this advantage of open entity to solar energy application. With research considered, the upper cover of the conveyer system has been replaced by implementing standalone solar panels with suitable capacity which can assist and propel the conveyor motor. The results portray a positive output in terms of energy efficiency and cost analysis.

1. Introduction

At present conveyor systems plays a vital role in any mining industry the effort of preliminary step of conveyor design is majorly focused on lower energy and reducing the pollution to the atmosphere. Many researches have contributed to lower the resistances in the belt for improving the energy efficiency \cite{1}. A basic design of the conveyor system is based on the calculation and its real time experiments, which are the base knowledge of source, without a verified theory one cannot develop an optimally designed belt conveyor system. For developing a conveyor line which could efficiently carry the material from one location to the other all the forces which occur along the route of the conveyor system are different zones of contact between the belt and its several supporting component which will efficiently carry the material without loss. Knowledge in different resistance forces on the conveyor system like idlers resistance, belt on idler rolling resistance, belt skirt boards resistance, belt bending resistance, flexure resistance, sliding resistance, scrappers, pulley etc., of the belt on idlers, in this regard is essential for designing and operating for long terms with in the design range \cite{2}. The major concern while designing the conveyor system is to calculate the driving forces on the driving pulley which could determine the choice of drive system and construction of the belt. Followed by the deciding on the power requirements for the driving the forces. Other calculations related to belt construction like width and length of the conveyor line is depend on the source and the destination of the material to be carried, particle size, maximum capacity and density of the material. International standard of 5048 provided a clear approach on considering all the set of resistances which intended to provide a
better method of conveyor design calculations [3]. Annually more than 2.5 million conveyor system are in operation in the world, for which the conveyor system is the major energy consumer of the industries, several smart solutions are introduced to optimize the operating modes and reduce the energy needs which could limit the exploitation costs. For the betterment several handling techniques are introduced like lifting, belt conveyor or roller tables, overhead conveyor with or without trolley, AGV’s. all these systems are categorized into manually operated conveyor system and automated conveyor system. Several components are associated with belt conveying system is show in the Figure 1. Improvement of the energy consumption of the belt conveyor system will be achieved only by the optimizing the equipment and operation level. Shirong Zhang and Xiaohua Xia provided several techniques for improving the efficiency by optimizing the equipment associated with belt conveying system [4]. As per the Indian statistics the state of Meghalaya in India holds the longest single-belt international conveyor system, about 17 km long conveyor line conveys limestone and Jindal Power uses longest pipeline conveyor transporting coal for 7 Km stretch which is also a second largest conveyor line in the world [11]. In the Figure 2 shows the length of the conveyor system which can be an open source of solar energy helps in driving the motor.

![Figure 1: Typical Outline of conveyor system](image1)

![Figure 2: Longest conveyor lines in India (Meghalaya and Jindal Pipeline conveyor)](image2)

Under the expenses point of view companies contribute nearly 70% for the maintenance and power consumption categorized into direct and indirect cost as show in the Table 1 [5]. A clear application analysis in optimizing energy efficiency of conveyor system by Schneider electric a French multinational company gave some milestones in reducing the cost in conveyor system. An analysis of comparison between the power and consumption carries four modes work in production,
standby unit, Stop- Safety mode for maintenance and Off- breakdown. In the handbook by Schneider electric provided solutions for reducing the energy consumption and improving the material handling capabilities, this also validated the operating condition of the conveyor system in different modes of operation plotted in the graph as shown in the Figure 3 [5]. Utilizing the smart technicians and roofs of the conveyor system by implementing solar PV system could provide a solution for reducing the power consumption cost to the mining industries.

Table 1: Expenses for an industry on Conveyor System

|                | Variable Expenses                                                                 | Constant Expenses                                                                 |
|----------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Direct cost    | -Raw products                                                                      | -Power consumption of the conveyor system and supporting equipment.              |
|                | -Manpower                                                                          | -Renting equipment for cleaning activities                                         |
|                | -Third party contractors                                                          | -Spare parts and maintenance cost                                                |
|                |                                                                                   | -Replacement and repair.                                                          |
| Indirect cost  | -Power consumption for maintenance activities and workshop                        | -R&D on solutions for problem associated with RCA.                                |
|                | -Miscellaneous supplies                                                            | -Investments                                                                      |
|                | -Fire hydrant systems                                                              |                                                                                   |

Figure 3: Graph Differentiating the Power and Energy consumption of Conveyor line.

With the growing impact on the environment caused due to the usage of fossil fuel, the alternative sources of energy such as solar, wind and bio energy has seen the picture to have been utilized to a potential extent. The forecast for reliability on fossil fuels predicts a clear downfall in the next few
decades. A research carried out by Swami [6] predicts the permanent drop in the oil production in 10-20 years. Combustion of fossil fuels contributes to the nearly three fourth of the energy supply in the world, while equally contributing to greenhouse gases and climate change [7]. Utilizing the inevitable source of solar energy has shown a tremendous response in domestic and industrial application world-wide. Solar energy is considered to be one of the substantial sources of energy [8]. Solar power has been utilized for more than half a century in small scale applications like electrification of rural areas, standalone solar homes, heating purpose in industries and space applications [9].

The utility of solar energy in the industries has shown high demand for both heating and electrical applications [10]. With marginal application, it is considered that it could broaden in future with a major usage of photovoltaic applications. The PV applications in industries effectively contribute towards both the electrical and thermal loads.

2. Methodology

2.1 Conveyor Design Calculations

Considering all the smart techniques for material movement from source to destinations is derived by considering all the resistant forces was given by ISO 5048 international standards [3]. The overall resistance to the motion of the conveyor line is given by several resistances which are classified as

\[ F_D = F_M + F_S + F_{Spl 1} + F_{Spl 2} + F_{Slo} \]  \hspace{1cm} (1)

Our proposed ideology of conveyor system in the industrial application for transporting material has been taken into consideration with reference literature survey. An assumption on the conveyor has been mentioned in the given Table 2, based on the driving forces by considering all the resistances of the system from equation (1) four transfer lines with three transfer towers from the source to destination with a distance of 523m covering a total roof area of 2,624.7 m² and transfer tower roof area of 376 m² having two way conveyor line for
which material can be unloaded from the ship to the recliners and vice versa, assuming all the conveyor lines are on the flat bed.

### Table 2: Belt Specification details

| Conveyor line | Length (m) | Belt Width (m) | Belt Length (m) | Design capacity |
|---------------|------------|----------------|----------------|----------------|
| Conveyor 1.1  | 161.46     | 1.6            | 322.928        | 3400 TPH       |
| Conveyor 1.2  | 62.33      | 1.6            | 124.672        | 3400 TPH       |
| Conveyor 2.1  | 192.53     | 1.6            | 385.07         | 3400 TPH       |
| Conveyor 2.2  | 108.12     | 1.6            | 216.25         | 3400 TPH       |

### Table 3: Driven Motor Specifications

| TT  | Power | Peak Current | RPM | Capacity | Belt Speed |
|-----|-------|--------------|-----|----------|------------|
| TT 1| 400 kW| 27 A         | 1485| 3000 TPH | 4.5 m/sec  |
| TT 2| 400 kW| 27 A         | 1485| 3000 TPH | 4.5 m/sec  |
| TT 3| 400 kW| 27 A         | 1485| 3000 TPH | 4.5 m/sec  |

*Note: Each TT- Transfer Tower has two motors for loading and unloading of material*

2.2 Solar PV sizing and Output factors:

In order to electrify or propel an area with solar power, the sizing of the photovoltaic cells is an essential aspect to be achieved. The sizing focusses on improved efficiency and minimal costing on the system. The required parameters include the energy demand by the system, area of the space, incoming solar radiation, the wattage and relative efficiency of the solar PV cell which has been chosen. This research focusses on integrating solar photovoltaic modules on the roof of the conveyor belts in the industries. The output in terms of electricity can be utilized to propel the conveyor belt motors thereby reducing the load on the grid.

2.3 Load Characterization:

The conveyor belts are driven by heavy duty 3-phase motors with a capacity of 400 kW and 27A and run at nearly 1485 RPM. The power of the motor comprises of 27 Amp at peak load conditions and 12 Amp at no-load conditions with a driving torque of 2500 Nm. The consumption of electricity from the grid is dependent on the loading capacity dumped on the conveyor belt. With reference to Table 2 the entire systems consist of 6 motors incorporated in to the three transfer towers for loading and unloading conveyor lines. The total capacity of energy consumed by the motors either loading line or the unloading line is 1200 kW.
3. Results and Discussions

3.1 Area and PV Cell Characterization:

The total available roof space of approximately 3,726 m² to set-up the PV modules. In order to supplement the grid connection with the solar panels installed on the roof of the transfer towers and the conveyor belts, the sizing of the panels have to be carried out with a high output 325 Watts, 72 cell Polycrystalline PV modules. The panels characteristics are; Vmp: 35.9 V, Imp: 8.36 A, Voc: 44.50 V and Isc: 8.83 A. The panel area comprises of 6.4 ft in length and 3.2 ft in width. Each panel cover an area of 1.9 m² which can be spread out in the prescribed area. As the power generated by using solar PV in the available area accounts to 630KW, which comprises of 50% of total power required for either the loading or unloading line of the conveyor system with 3000 TPH capacity using ST1600 steel cord belt.

3.2 Cost Analysis of PV in Conveyor system:

Considering the prescribed area of 3726 m² which can be utilised to implement 325 W PV modules on the roof of the conveyor system, this system requires 1940 numbers of solar panels.

- The total cost of the PV panels- 2,42,50,000 INR [12].
- Accessories to install the system- 57,50,000 INR.
- Expected total cost of the entire system is approximately- 3,00,00,000 INR.

According to the motor specifications and load conditions, the motors consume 2,40,000 units/day for 20 hours of continuous operation either in loading/unloading condition is grid dependent. By considering the functionality of solar PV with 8 hour of active radiation can produce 5000 units/day, which is equivalent to 20% of the energy consumed by the motors from the grid. In regard to the cost analysis and considering the industrial unit price, application of solar energy can save 55,000 units of grid power a day is equivalent to 2,00,75,000 INR per year. Considering the cost analysis, it can be assumed that the ROI (return on investment) can be expected with in a span of 20 months.

3.3 During Diffused Radiation:

With the geographical conditions, the diffused radiation is the most considerable factor which varies with respective to weather conditions. On a diffused radiation day, the contribution of energy from the PV system is minimal; conveyor system can be driven by the energy source from the grid.
4. Conclusion:

This research concludes the optimum usage of PV modules to supplement the grid connected electrical energy. With the analysis carried out, it shows that nearly 1940 solar panels can be implemented in the prescribed area which is capable of producing 630 kW of energy which is nearly 50% of the grid energy. In case of lower conveyor capacity where 1500THP is required, belt of ST1250 can be utilised for which 200KW motor can be used where entire loading or unloading line of the conveyor system can be driven by Solar PV panels.

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