KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

PROJECT REPORT

Design and Implementation of Dynamic Line Rating For Electric Lines

A **Final year project report** submitted in partial fulfilment
of the requirements for the degree of
Bachelor of Engineering

by:

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CERTIFICATION

FINAL YEAR PROJECT REPORT

ON

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Abstract

Dynamic Line Rating is also known as real-time thermal rating. It is a philosophy aimed at maximizing the load current when the environmental conditions allow it without compromising safety. This project uses the models given by the IEEE standards and applies the philosophy through an experimental setup. This project presents an analysis of different parameters to be considered for the dynamic rating of overhead transmission lines. Taken into consideration are the wind velocity, solar irradiance, ambient temperature and temperature of conductor for determining the rating of conductor. This report presents the analysis of the data of the above parameters and predicted dynamic rating using a predictive model. The predicted rating can be used to optimize a transmission network's capacity of handling power by taking system health & overall grid stability into consideration. A dynamic line rating model has been implemented in this project by making use of the Arduino UNO & National Instrument's LabVIEW as a data acquisition platform.

Acknowledgement

We would like to express our gratitude to the Department of Electrical & Electronics Engineering for providing us with the wonderful opportunity to work on this project. We feel indebted to our supervisor Dr. Samundra Gurung for constant guidance, encouragement and support throughout the duration of this work. It was a wonderful journey being supervised by him. We have not only gained extensive knowledge about the subject matter at hand but have also been able to develop a careful research attitude.

We also feel thankful towards the Department of Mechanical Engineering & Department of Environmental Engineering for their support in gathering the required data/resources for our preliminary analysis & experimental setup. We extend our thanks to colleagues in the Power & Control specialization and our juniors, who helped us foster an academic and friendly environment that made our work easier and more enjoyable.

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CHAPTER 1: INTRODUCTION

The ampacity of an overhead transmission line is the maximum electrical current that a power line can carry considering given tensile strength and sag of the conductor within limit. In practice the ratings given to the power lines are determined by the most critical circumstances and high reliability. Dynamic Line Rating (DLR) is the ability to vary the thermal capacity of an overhead transmission or distribution power line dynamically in real time, depending on the varying environmental conditions (ambient temperature, solar radiation, and wind speed and direction. The aim is to maximize loading at every point in time. The physical and electrical factors that affect power transmission are line currents, sag/tension, physical and electrical properties of the material and construction of conductors and insulations. Some of the weather factors are wind speed, wind direction, solar radiation, and ambient temperature.

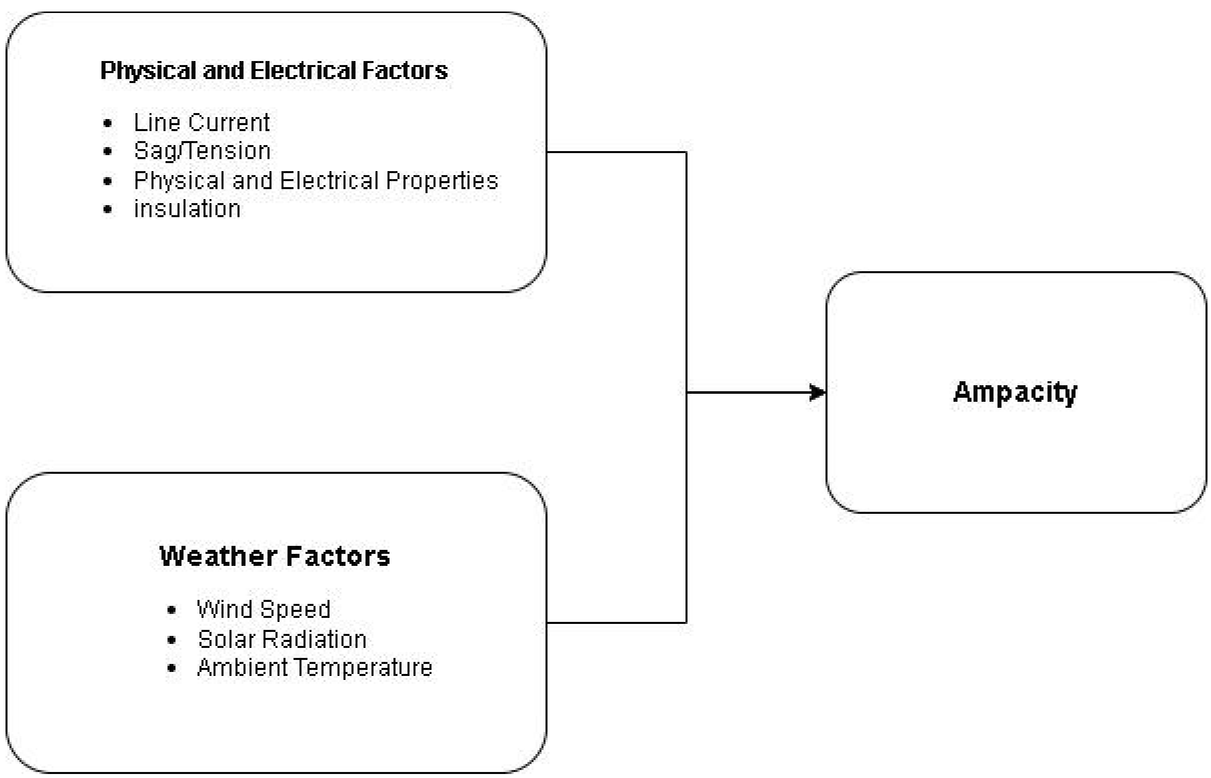

Figure 1. Factors affecting Ampacity

1.1 Methods of calculating the real-time thermal rating

There are different commercial methods available for employing and determining dynamic power line ratings. The different commercial methods can be based on weather monitoring, line tension metering, line temperature etc. There has been development of the DLR in recent years especially in the field of wind power development in countries like Central Europe, UK and USA. It is a technology used to increase the ampacity of electric overhead lines. Currently, conservative static seasonal estimations of meteorological values are used to determine ampacity. In a DLR framework, the ampacity is estimated in real-time or quasi real-time using sensors on the line that measure conductor temperature, tension sag or environmental parameters such as wind speed and air temperature [1]. Because of the conservative assumptions used to calculate static seasonal ampacity limits and the variability of weather parameters, DLRs frameworks are considerably higher than static seasonal ratings.

For a model to base our analysis on, as evidenced the results presented in various works [1], [2], [6] & [7], the standard model provided by IEEE [4] has produced excellent results. The model is completely characterized by measurements of 5 parameters; global horizontal irradiance, wind velocity, wind incidence angle, ambient temperature, conductor temperature. The model is described by the steady-state heat-balance equation in a conductor:

$$q_c + q_r = q_s + I^2 R(T_c)$$

$$I = \sqrt{\frac{q_c + q_r - q_s}{R(T_c)}} \text{............. eqn (1)}$$

Where:

q_c= conventional heat loss rate

q_r =radiated heat loss rate

q_s= solar heat gain rate

R is a function of temperature of conductor.

1.2 How DLR is better than existing systems?

DLR minimizes the infrastructure expansions required to supply steadily rising energy consumption by allowing an overhead line to operate at its thermal limits. Imagine if we could efficiently maximize transmission line loading in real-time. By increasing the average power carried by a power line and applying it to the whole power grid, the flow of power can be improved on a national scale, eliminating overloaded areas and future-proofing the existing infrastructure for a longer period. It is crucial to keep in mind that this technology's role is to build a feedback system for generating stations & load dispatch centers to cooperatively respond to. Therefore, this technology does not boost the power generation potential of any grid.

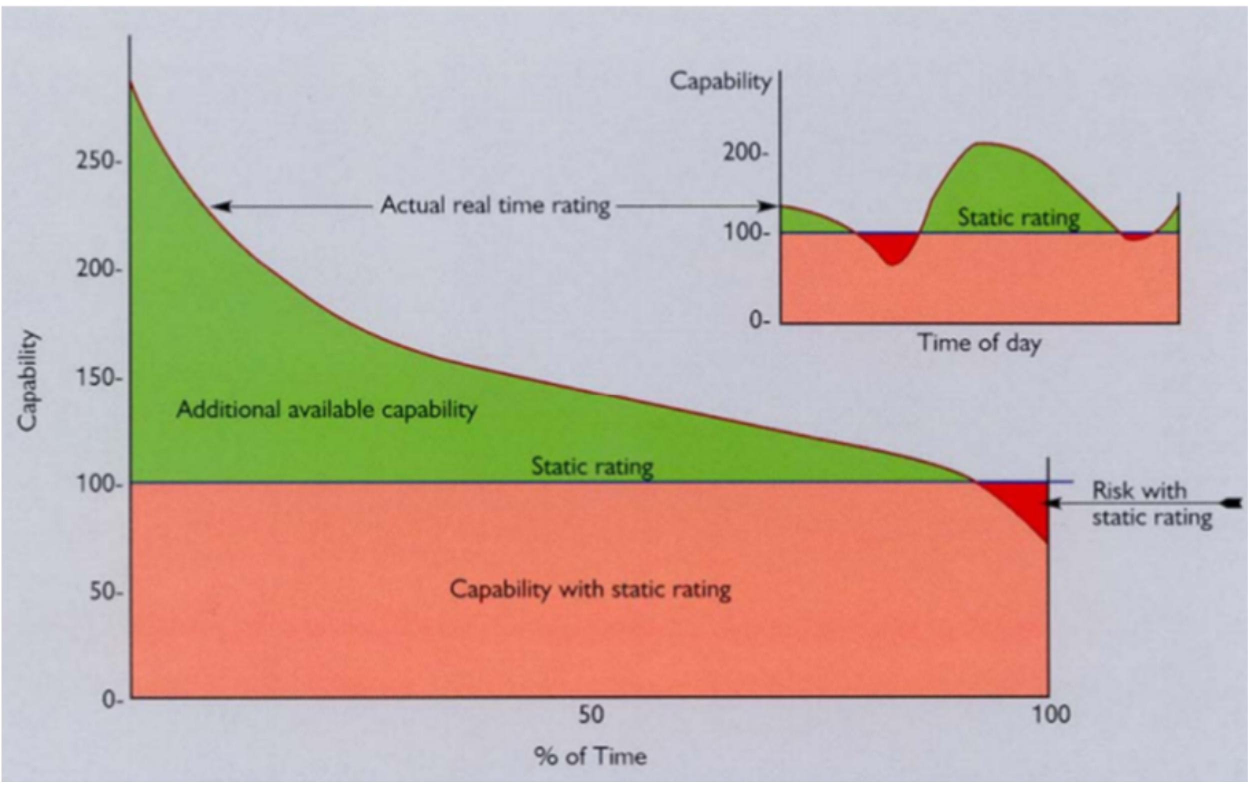

Figure 2. Real Time Ampacity ratings vs Static Ratings [2]

1.3 The problem statement

Currently, the ampacity of a transmission line is completely determined by the manufacturer who calculates the ampacity of the cables considering some static conditions also called Static Line Rating (SLR). SLR is calculated using the worst-case scenario and is always constant meaning the wires are not used optimally. The worst-case scenarios are defined as (Wind Speed = 0.6 m/s, Conductor Temperature = 75°C, Solar Irradiance = 1000 W/m^2). This opens some headroom for utilities to calculate the DLR of power lines to accurately estimate the available headroom for extra current handling capability their lines have at different points in time throughout the day.

These conductors, or rather, the limited information we have on them disallow us to always satisfy the peak load demand which lead to large-scale grid reinforcement plans for when the load demand starts encroaching the available infrastructure. Such a system expansion is not only about optimizing the gains, but also about optimizing the losses as sometimes, unfavorable environmental conditions deem the power lines unable to carry their SLR currents & get overloaded meaning that through DLR utilities can improve the resilience of the system making sure that such risky events are accounted for and damage isn’t caused due to overloading. This is made abundantly clear by Figure 2, towards the right end of the curve, where the ampacity of the line encroaches the static rating, meaning that even though the power line is incapable of withstanding a full-load current, utilities might proceed with allowing it due to an incomplete knowledge of the state of their lines.

By use of DLR, the conductors can be optimally used by safely increasing their transmission capacity up to 20-30%, based on current studies [1] … [7]. Another benefit of such a scheme is it solves the energy-transfer bottleneck problem with large power lines used in cross-border energy trade where a nation wants to export as much energy as it can to maximise revenues.

1.4 Objectives

- Gather information on the current state of DLR technology to learn about dynamic line rating and its implementation
- Draw evidence of improvement of ampacity and establish a correlation of variables to the ampacity of lines
- Develop a data acquisition system to acquire meteorological data for real-time DLR monitoring of electric lines
- Use of predictive models for DLR forecasting from hour-ahead to day-ahead schemes

1.5 Methodology

- Design of an experimental setup by taking important parameters into consideration.
- Using the ampacity formula given in IEEE Std-738 [4] i.e. mentioned in eqn (1) to calculate the system current.
- Analyze the line ampacity with varying parameters.
- Obtain results from implementing the IEEE model in the experimental setup and employ any required correction factors to address the model's limitations for small-scale models

1.6 Limitations

- Since all the physical parameters are not taken into consideration, the exact ampacity cannot be known. However, the estimates are very close to the exact rating for overhead transmission lines.
- The sensors used are not precise which makes it such that the ratings too are not as precise as they would be with high-precision sensors.

1.7 Organization of Report

This report is organized into five main sections. This chapter, the introduction is supplemented by a literature survey of DLR, the second section. The third section is project methodology. The fourth section presents the validation of DLR model, experimental setup for implementing the IEEE ampacity formula and how it can be used for DLR system & development of a predictive model to forecast ampacity.

1.8 Summary

DLR minimizes the infrastructure expansions required to supply steadily rising energy consumption by allowing an overhead line to operate at its thermal limits. This report presents the implementation of the IEEE standard to calculate the dynamic line rating of conductors considering different parameters.

CHAPTER 2: TECHNOLOGY AND LITERATURE SURVEY

There is already a large body of existing research on dynamic thermal rating of power lines. For readability, we will be using the term 'lines' instead of 'power lines' throughout this document. Many of these follow the IEEE Standard 738 [4]. One of the earliest works in developing this technology was done by Davis [5] where he calculated the effect of wind, solar radiation & ice loading on the ampacity of lines. A recent review by Fernandez et al. [1] has summarized many of the technologies that have been developed which we will be discussing in this section. To quote Seppa [7] 'The cost for monitoring a circuit, including installation of the equipment and the software, is less than 2% of the cost of achieving equivalent gain by conventional techniques.

The actual limit for transmission line current carrying capability is a combination of the influence of the line heating and cooling [6]. The limiting feature may be either the actual line temperature (conductor material issues), or the decreased conductor clearance from the ground (jeopardized by increased sag due to conductor heat expansion). The more common limiting feature is the sag of the line. This figure illustrates further the influence of combined impact of four variables on ampacity for a Zebra type conductor (cross-sectional area: 484.5 sq.mm, Resistance: 0.0674 Ω/km).

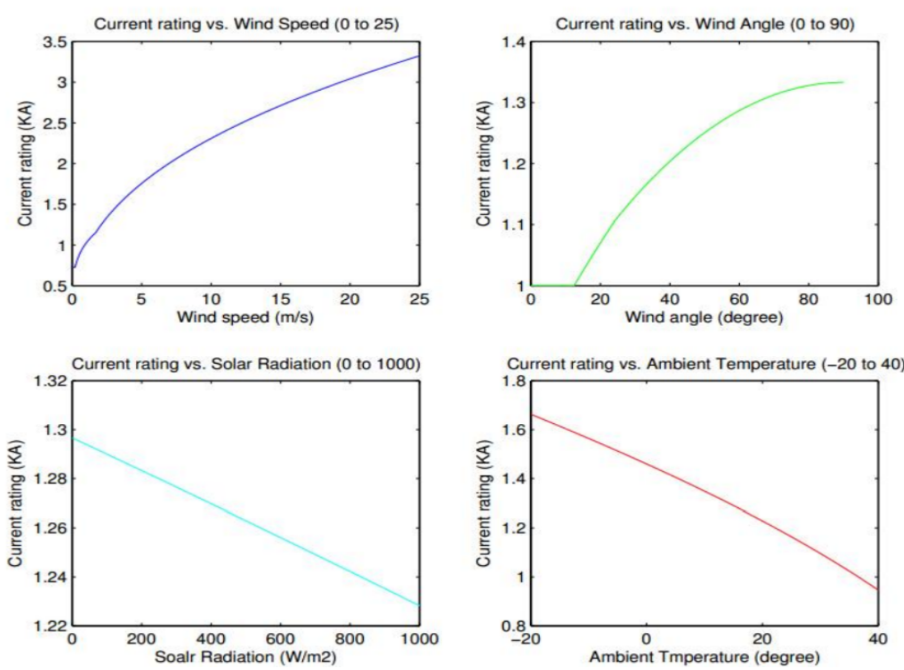

Figure 3. Ampacity vs Different Parameters [3]

DLR is not an alternative to anything, it is a technology which has been known for a long time without an economical means of implementing it. Benefits of DLR were not accessible to people of yesterday due to the global micro/Nano-electronics industry being in its nascent stage. Now that devices like radar-on-a-chip [8] are possible, DLR technology is perfectly positioned for success at scale. Much of grid-congestion occurs when components in the network reach their thermal limits due to the ever-increasing demand for electricity, with the most recent addition being global adoption of Electric Vehicles. To reiterate, DLR allows an overhead line to operate at its thermal limits which makes it possible to reduce the infrastructural expansions necessary for supporting consistently growing energy demands. Imagine if safely maximizing the loading of every transmission line was possible in real-time. The average power transported by a line could be increased and with it implemented on multiple transmission lines, have the national & international electrical energy dissemination efficiency increased.

CHAPTER 3: METHODOLOGY

3.1 Procedure

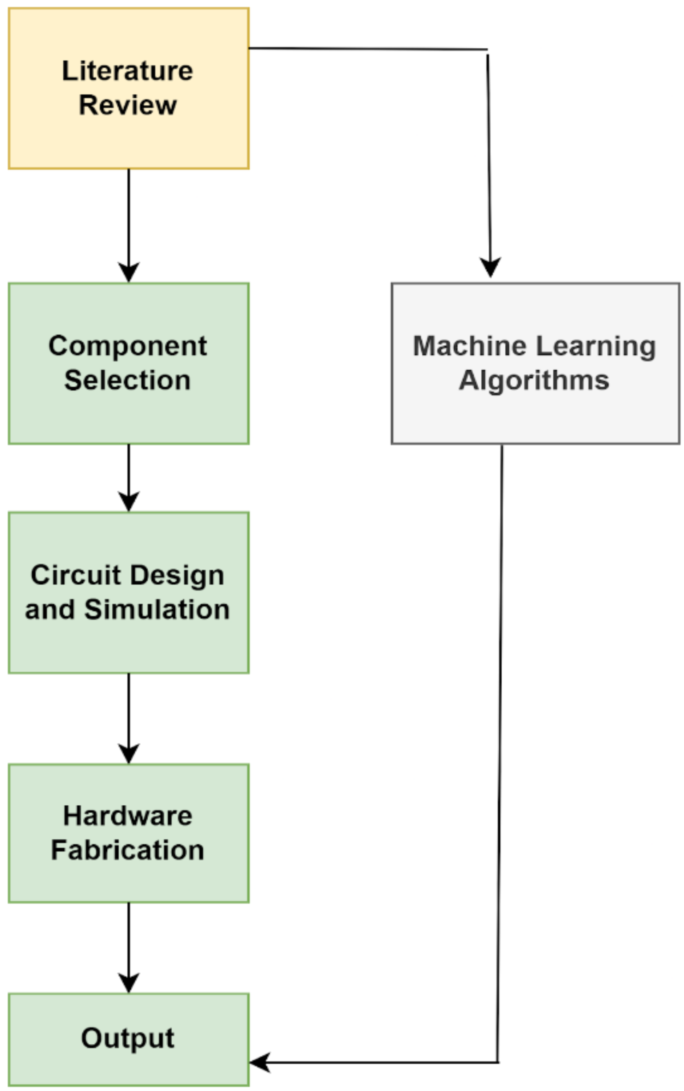

Figure 4. Flow Chart of the System

Our project methodology is mainly divided into two parts, hardware design for monitoring & machine learning for forecasting. They can be further broken down as:

1. Review & documentation of existing literature and DLR methodologies

    - Review of commercial solutions & current research on DLR

- Selection of the most economically & technically appropriate variables to monitor

2. System block diagram design

   - Overall system with instrumentation system architecture & experimental setup

3. Collection of materials required

   - Listing out all required parts, materials & components
   - Sourcing required materials and parts
   - Procurement of locally unavailable parts & components

4. Experimental setup

   - Design, organization & calibration of an instrumentation system to monitor line parameters
   - Design of experiment proposed in Figure 5 using 7/22 stranded ACSR
   - Design of communication system to send acquired data to micro-controller

5. Forecasting

   - Design of different machine learning models to train data
   - Training, testing & cross-validation of models using collected data
   - Deployment of validated data as an online model

3.2 System Overview

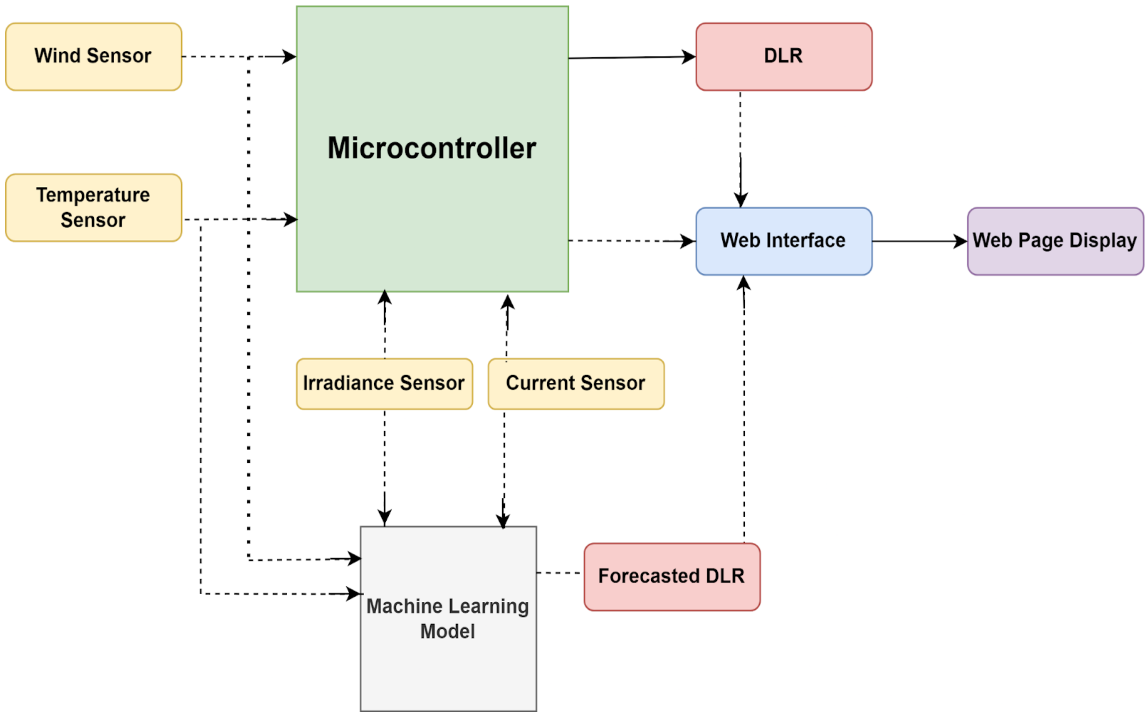

Figure 5. Block Diagram of the project.

The proposed system will be centered on a program that continuously calculates ampacity based on the measured parameters [4] from the sensors and keeps feeding the measured data to a predictive learning model. The forecasts as well as real-time data from the model are to be fed back to a control station and will be visible to view & monitor an interface

ARIMA (Auto-Regressive Integrative Moving Average), which is a common predictive model will be used for the prediction part. Its equation is given as:

$$y'(t)=c+\varnothing_1 y'(t-1)+\varnothing_p y'(t-p)+\theta_q \epsilon(t-1)+\ldots+\theta_q \epsilon(t-q)+\epsilon t \ldots\ldots\ldots\ldots\ldots \quad (2)$$

3.2 Components Survey

1. Current Sensor: Clamp meter (For precise Current Ratings)
2. Temperature Sensor: LM 35 Temperature Sensor (Linear and rages from -25 to 150 Celsius)
3. Solar Irradiance Sensor: Solar cell based solar power per unit area sensor (Simplest method to detect change in Solar Irradiance)

4. Wind Sensor: Anemometer
5. Micro-controller, preferably with built-in wireless communication module (Arduino as it is easily available and cheaper in comparison to other microcontroller)

3.4 Budget Estimation

S.N	Particulars	Dimensions	Quantity	Price (in NRs)
1	Solar Cell	-	1	500
2	Micro controller	-	1	880
3	Temperature Sensor	-	2	100
4	Miscellaneous (Hardware Setup)		-	3000
Total				4480

3.5 Experimental Setup

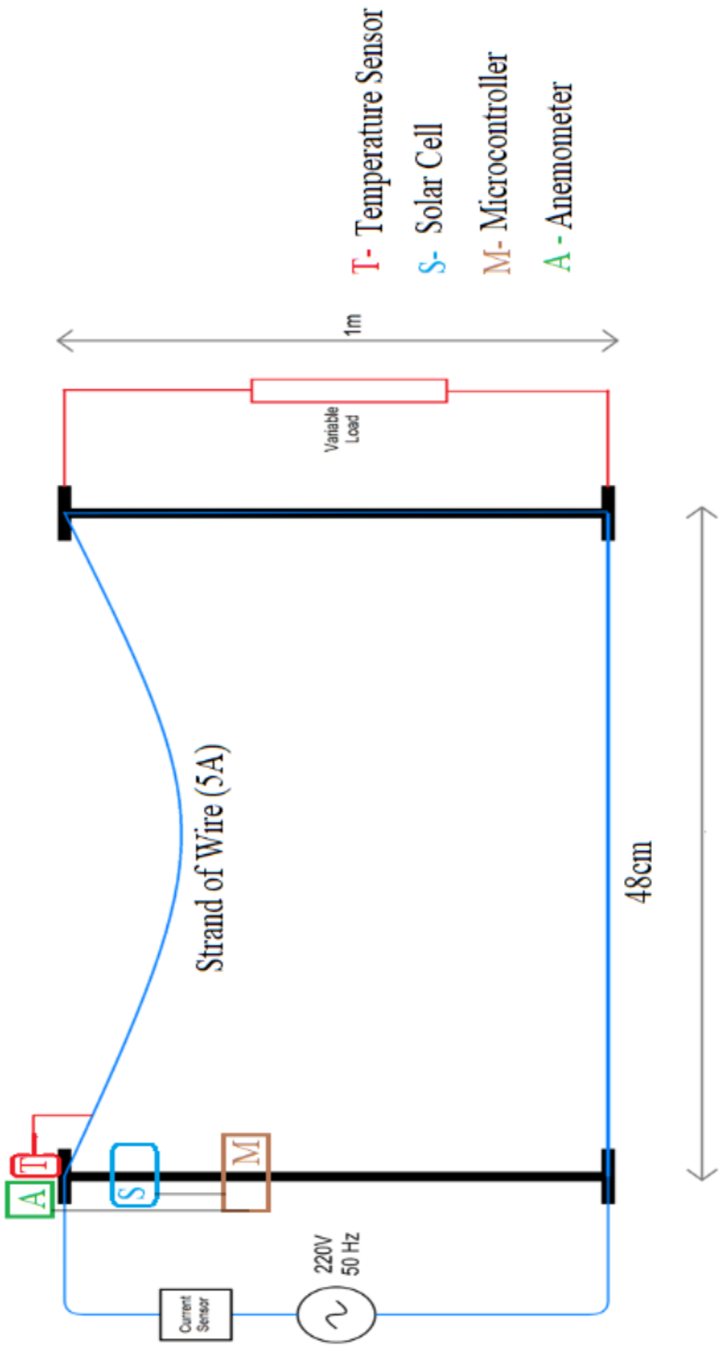

Figure 6. Experimental Setup expected for our Project.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Simulation Results

Using this heat balance equation on a 7/54 ACSR conductor, MOOSE (diameter: 31.77 mm, total cross-sectional area: 597 sq.mm) which has a nominal ampacity of 900 A the following curves were obtained showing variation of the current against environmental parameters.

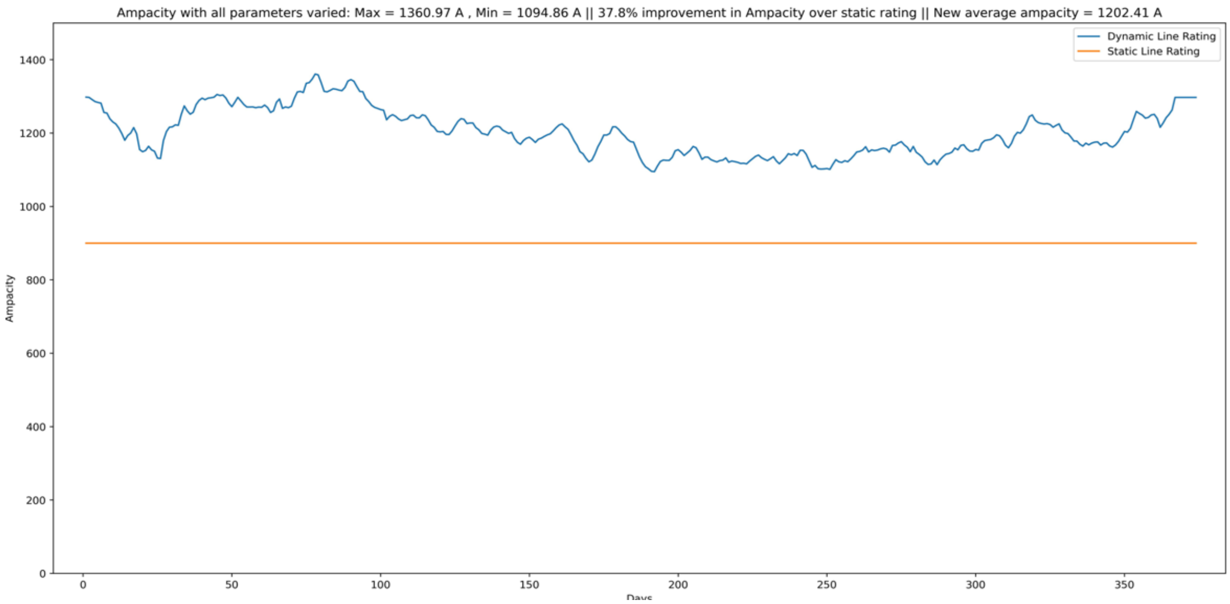

Figure 7. DLR with all parameters varied.

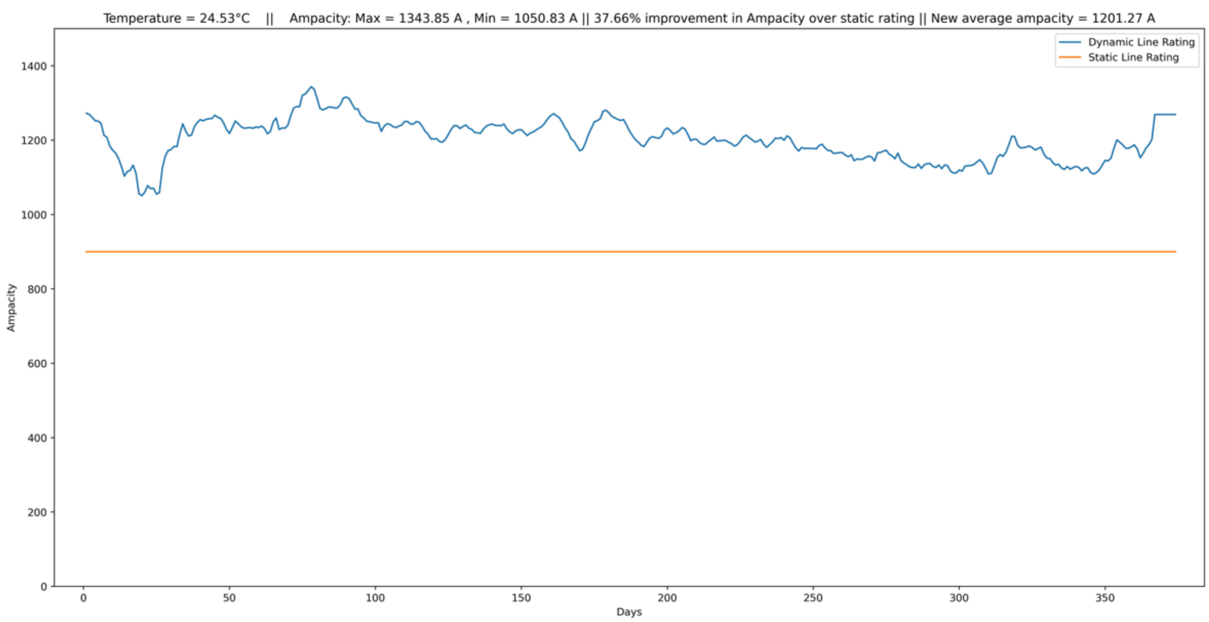

Figure 8. DLR with Temperature held constant.

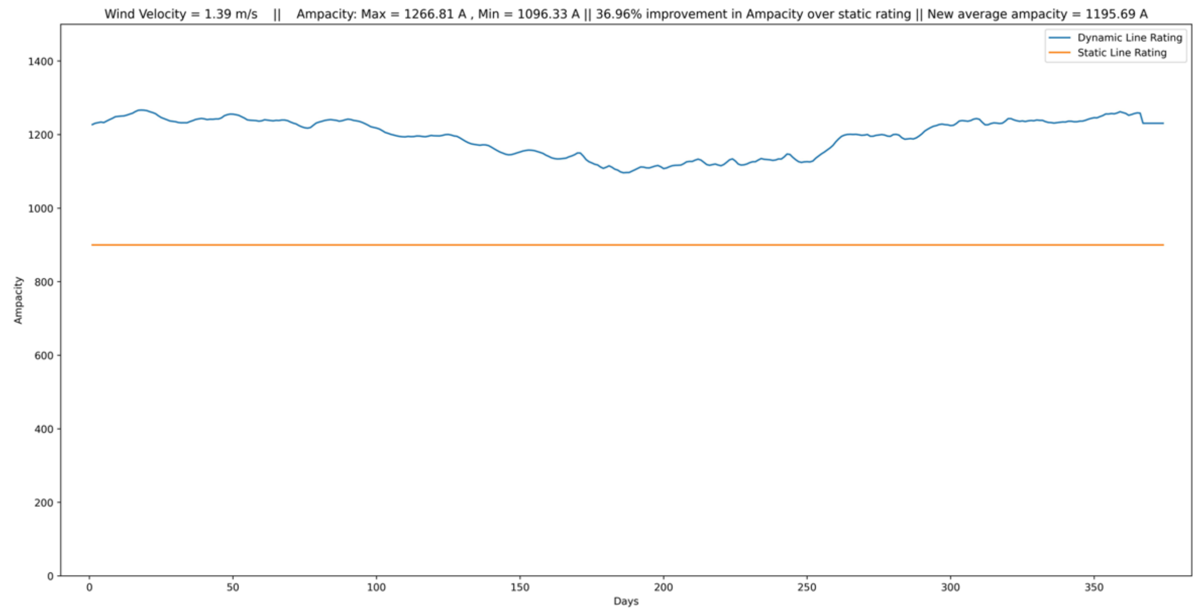

Figure 9. Temperature with Wind Velocity held constant**.**

The curves clearly highlight the possibility of improving the average ampacity of any conductor. For MOOSE, using all data on major environmental parameters obtained from Dharan Weather Station parameters and assuming wind incidence angle as 90°, the ampacity was obtained. The data shows the average ampacity over a period of 374 days (about 1 year) to be ~1200A which is a ~37% improvement over the existing capability of the line. The length of the line in this analysis is 1m. In terms of Wh, this is a significant improvement. For example, if transmission voltage is 132 kV, the energy that can be transferred over a year is 1.44 GWh compared to 1.08 GWh at 900A static rating.

Using these facts and figures, an auto-regressive predictive model was trained to learn to predict future trends in the incoming data. The Auto-Regressive Integrated Moving Average (ARIMA) model which is a linear predictive model given by the eqn (2). In the equation, three parameters can be chosen characterizing the model. They are referred to with the notation ARIMA(p,d,q).

Past values of the output 'y' are a finite window of values. The 'p' parameter represents the order of the Auto-Regressive model i.e. how many past values to consider, 'd' gives the order of the Integrative model & 'q' gives the order of the Moving Average model. gives the values of the auto-regressive coefficients. The residuals are quantified as the model performs regression. The 'd' parameter characterizes the window of the residuals. Finally, the 'q' parameter decides the no. of moving average terms.

In a nutshell, the models predict a line of best-fit that encodes the periodicity of the data seen and creates similar patterns of data by extrapolation using the fitted attributes. This is a relatively simple but robust way to capture the components of seasonal phenomena such as rain patterns throughout the year. Consequently, the ratings of overhead transmission lines also show seasonal variation in the preliminary plots. This hint can be further explored to verify that indeed, the data shows seasonal variation and can be used to train a simple predictive model. This was implemented on the obtained curves to train the ARIMA model and obtain this predictive curve which can predict the ampacity of the line with reasonable accuracy.

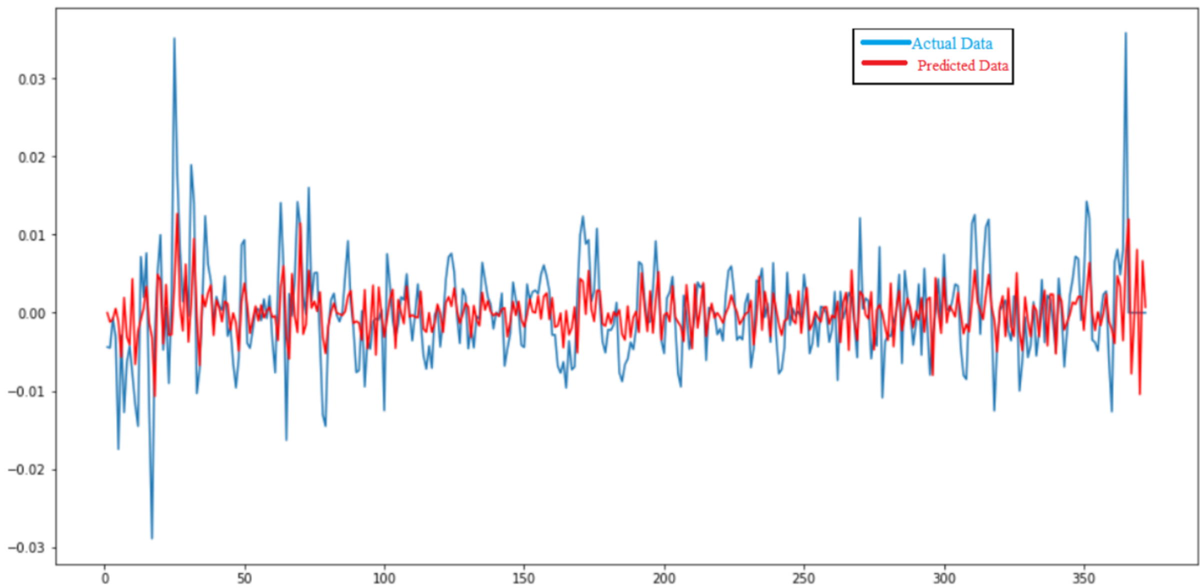

Figure 10. Residuals obtained from ARIMA model.

Figure 10, which is a plot of normalized residuals (deviation from a best-fit curve) clearly shows that the prediction using the model yields satisfactory results and hence provides a good way for system planners to plan their usage of DLR ahead of time.

Also relevant to this discussion is how highly correlated the environmental variables are to the ampacity of the lines. Intuitively, it's apparent that solar irradiance must be a relatively small contributor towards decreasing the line ampacity since the projected area of the conductor i.e. the area in direct contact to sunlight is a significantly small surface. On the other hand, the temperature of conductor might play a slightly greater role in natural convection or radiative heat-transfer due to the rate of cooling of the conductor being proportional to the temperature gradient of its temperature with air temperature. Wind seems to be the greatest contributing factor as forced convection through wind is a very efficient way of heat transfer from the lines towards surrounding air, which gets carried away quickly. This intuition is supported by zooming in on the data and picking 4 days, each representative of the four seasons.

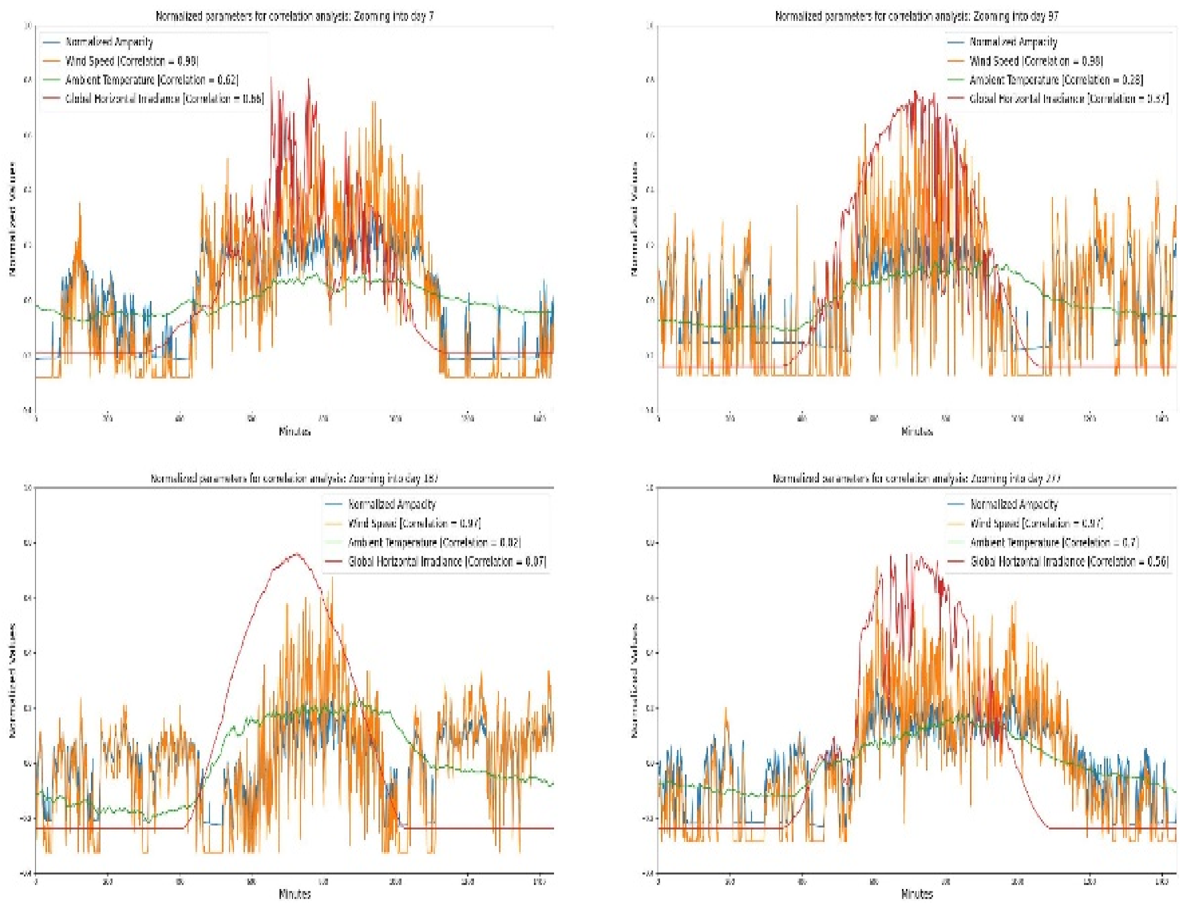

Figure 11. Sample Day Picked from Dharan Meteorological Data.

This clearly supports our intuition as wind correlation is high compared to irradiance and ambient air temperature. This is further verified by calculating the correlation for each day.

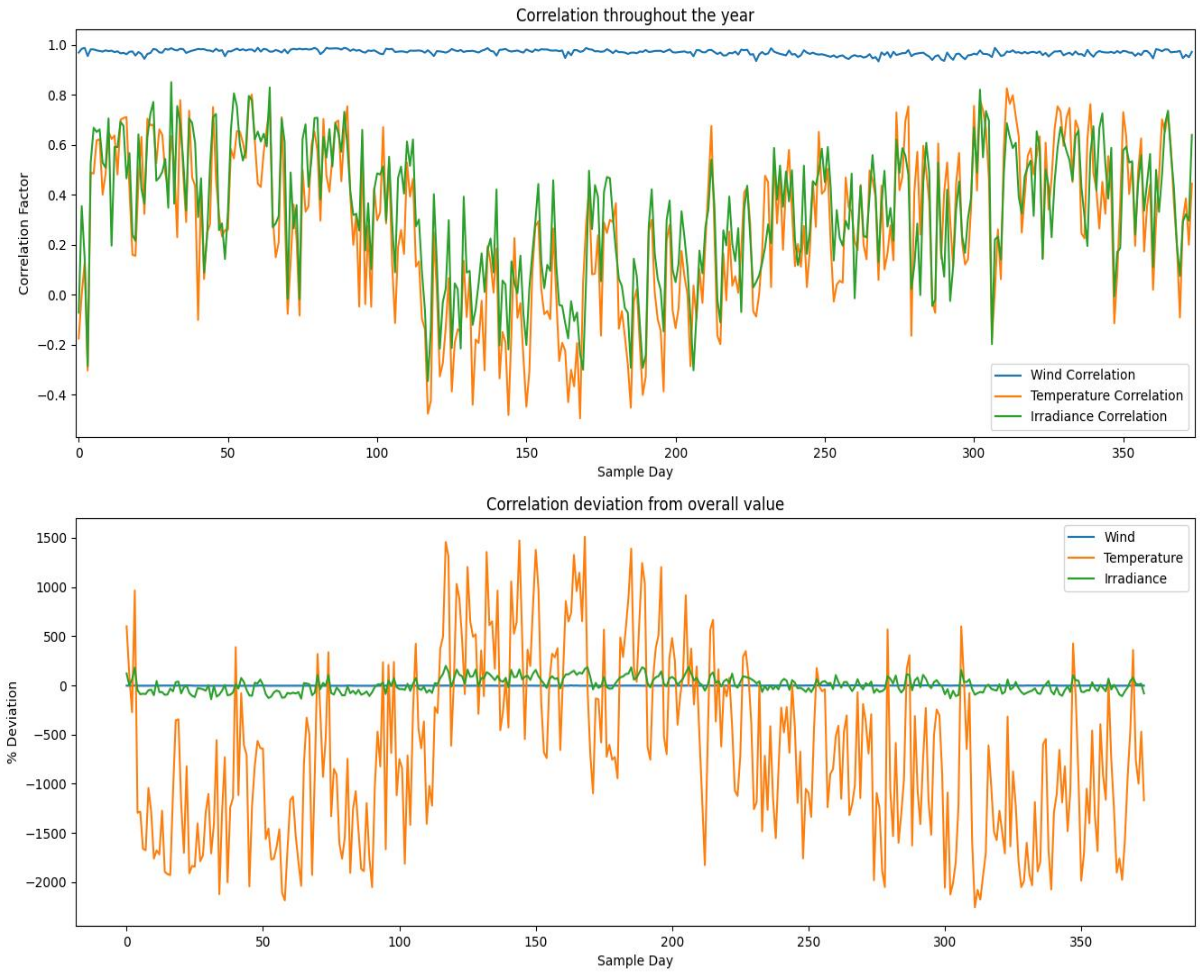

Figure 12. Correlation Deviation from Overall Value.

The value of the correlation coefficients is obtained as 0.97 for wind speed, 0.27 for ambient temperature & 0.37 for solar irradiance. Therefore, it's clear that wind speed is highly correlated to ampacity and is in fact, a cause for significant improvement in it. From Figure 12, it's apparent that air temperature and irradiance are negatively correlated during spring, summer & early-autumn, which is at the center of the graph and positively correlated during the colder seasons of late-Autumn and Winter.

4.2 Experimental Validation

With the help of an experimental setup the data of current, ambient temperature, wind temperature and irradiance were measured for different conditions. This section focuses on only a tiny portion of the data to explore different cases caused by varying environmental parameters. During this process the followings steps were taken:

- Wooden poles were made above which the strips of wire of rating 5A (Ampacity) were suspended.
- The load was an Electric Infrared Cooktop which draws current up to 8A and a nichrome filament heater was used as additional load of 6A.
- Clamp meter was used to measure the exact current flowing through the wires.
- LM 35 temperature sensors were mounted on the wooden poles at top for measuring air and conductor temperatures.
- A small fan of 5W which had 3 speed settings as shown in Table 1 was mounted.

Table 1: Wind Speed

Fan Mode	Wind Speed (m/s)	Revolution per Minute (RPM)
1	1.81	2040
2	2.3	2340
3	2.8	2700

- A highly sensitive anemometer was used to calibrate the measured RPM of the fan to wind speed using Hall Effect sensor.
- Solar cell of area 31.5 cm^2 with max output of 6.22 V was used to make a reference for solar irradiance.
- The no. of wire strips along with wind, load and temperature were varied for measuring the data.
- Arduino was used for data acquisition system which displayed the data as follows:


```
The Wind Data :0.00 m/s
Ambient Temperature = 72.34
Conductor Temperature = 21.02

The Wind Data :0.00 m/s
Ambient Temperature = 72.34
Conductor Temperature = 21.51

The Wind Data :0.00 m/s
Ambient Temperature = 73.31
Conductor Temperature = 21.51

The Wind Data :0.00 m/s
Ambient Temperature = 74.78
Conductor Temperature = 21.02
```

Figure 13. Data from Arduino Serial Monitor.

Here no external cooling was given, and the data was taken at night time with no forced convection, hence wind data appearing to be 0.

The overall hardware setup can be seen as below:

Figure 14. Hardware Setup.

The environment was taken such that minimum interference of wind, sun and other environmental parameters occurred for measuring parameters, first at zero wind condition and later with multiple wind settings. The cases of the data acquisition are:

Case 1: Effect of Changing Load on Wire Strand Temperature.

The varying load is applied with the help of a load varying knob in the Heater. As the load varies so does the current which dissipates more heat as a loss factor. The data was obtained as:

Table 2: Changing Temperature with Load.

Wire Strand	Ambient Temperature (c)	Conductor Temperature (c)	Load Current
1	19.55	34.21	3.47
1	19.55	50.34	4.55
1	19.55	63.54	5.1
1	19.55	74.78	5.63
1	19.55	90.91	6.07

The data in Table 2 was taken for a strand of wire without any wind

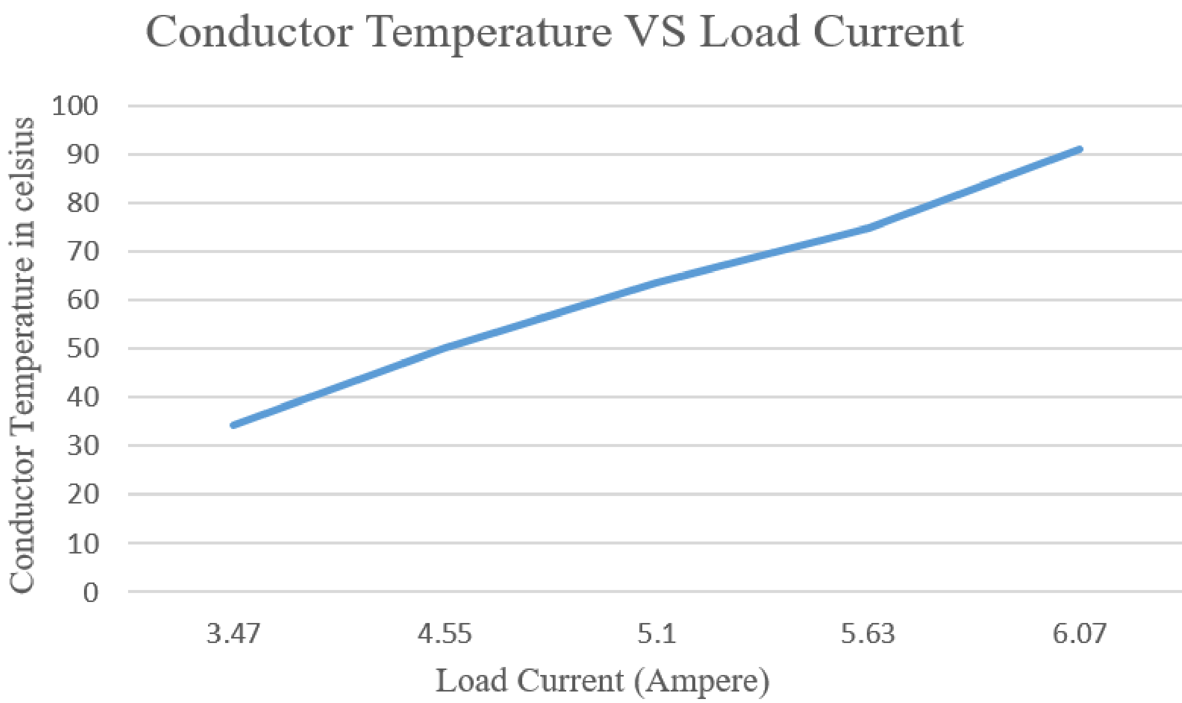

Figure 15. Wire Strand temperature VS Load Current.

Figure 13 shows that rise in temperature of conductor is directly proportional to the rise in the load current as expected.

Case 2: Effect of Wind on Wire Strand Rating

Wind was provided with the help of DC fan which had 3 different wind speed as mentioned in **4.2**. The ampacity was measured for only 1 wire strand at beginning by varying the fan speed and the conductor temperature was observed to be 74.78°C. Since the exact temperature of 75°C couldn't be obtained precisely, temperature within 3°C of it was considered to be sufficient for verification. The data obtained are:

Table 3: DLR based on Wind for 1 strand of wire.

Ambient Temperature	Wind (m/s)	Current Rating
19.55	0	5.63
19.55	1.8	6.19
21.02	2.2	6.60
21.99	2.8	7.207

From Table 3 data, it can be seen that there is a gradual rise of current rating as wind speed increases and the strand temperature is 74.78 C. The ampacity of this wire strand is considered to be 5.63A which is obtained at 0 m/s wind velocity. A graph is plotted between wind and current to know the dynamic line rating of the wire considering static ampacity of wire to be 5.63A.

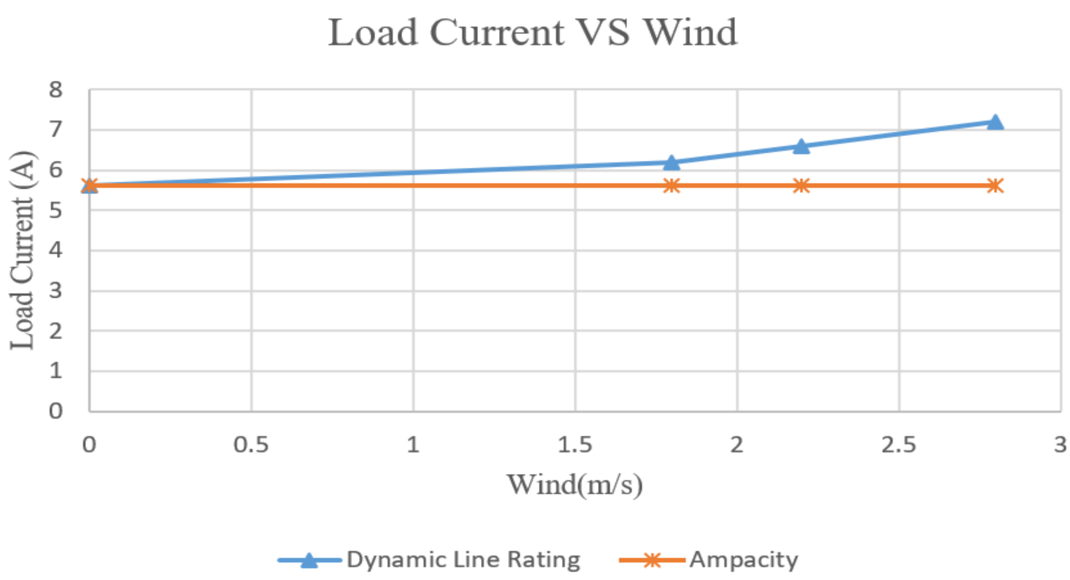

Figure 16. DLR vs SLR of 1 Wire Strand with Varying Wind.

Figure 14 shows there is headroom for current above ampacity with varying wind speed which can be used to optimize the use of the wire.

Similarly, the data obtained for 3 strands of wire are:

Table 4: DLR based on Wind for 3 strands of wire.

Ambient Temperature	Wind (m/s)	Current Rating (A)
28.8	0	10.23
26.39	2.1	12.2
26.1	2.8	12.38

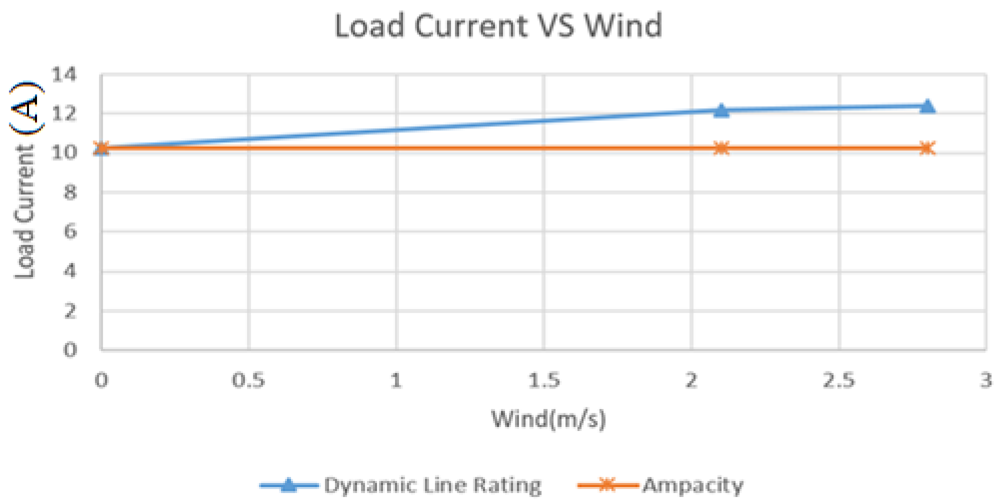

Figure 17. Load Current vs Wind for 2 Wire Strand.

Case 3: Effect of Solar Irradiance on Wire Strand Rating

For calculating the load current with varying irradiance, we have considered following points:

- Varying solar irradiance is done by using a Filament Heater of Steps.
- Solar Cell is used to detect the change in Solar Irradiance.
- The voltage drop of 0.6V across Arduino input is considered to be $300 W/m^2$ as a reference.
- The effect of the rise in temperature due to heater is also considered but can be differentiated from change in ambient temperature.

The data obtained from the setup is as follows:

Table 5: DLR based on Irradiance.

Ambient Temperature (C)	**Conductor Temperature (C)**	**Irradiance (W/m^2)**	**Load Current (A)**
30.3	75.76	288.37	11.7
31.28	75.76	409.21	9.6

The graph obtained from Table 5 data is:

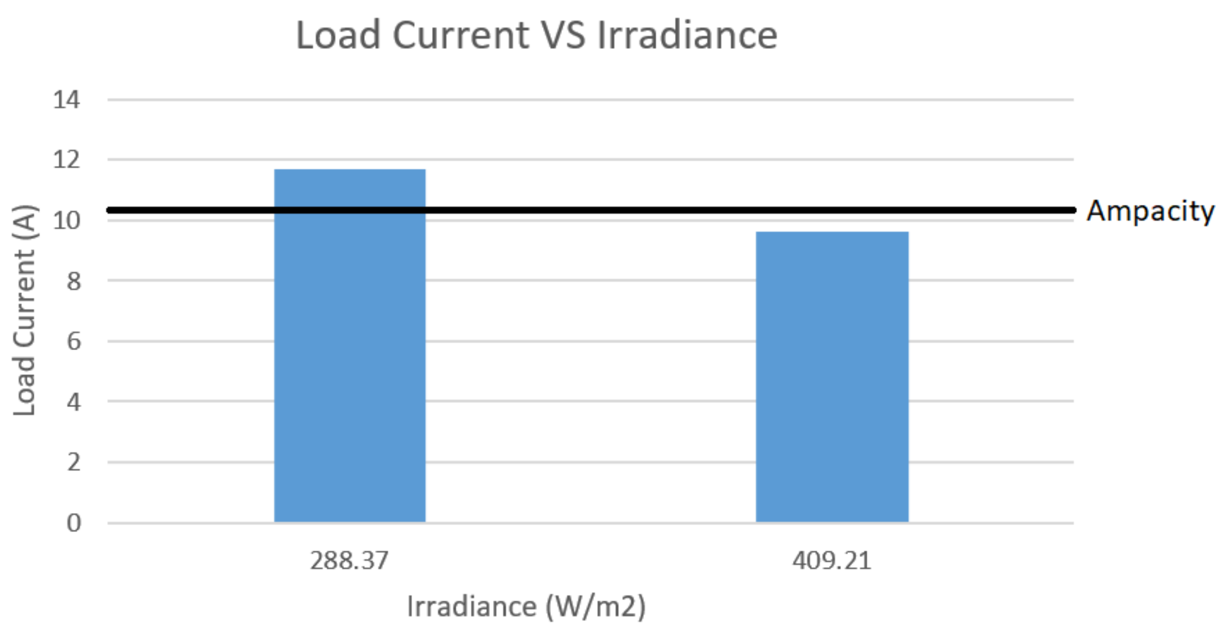

Figure 18. Solar Irradiance vs Load Current (DLR).

Figure 16 shows that the increase in the solar irradiance decreases the dynamic line rating of the wire strand. The irradiance in the second case has a rating below the DLR which could be the result of increase in ambient temperature of the testing room due to the generated heat.

4.3 Result from Data Acquisition System

For the data acquisition system microcontroller (Arduino) was used and input was taken from LM 35 Temperature sensor, and solar cell. The detection of wind speed was done by using Hall Effect sensor which calculated RPM and based on that wind speed was known. LabVIEW was used as Data Acquisition System along with Arduino.

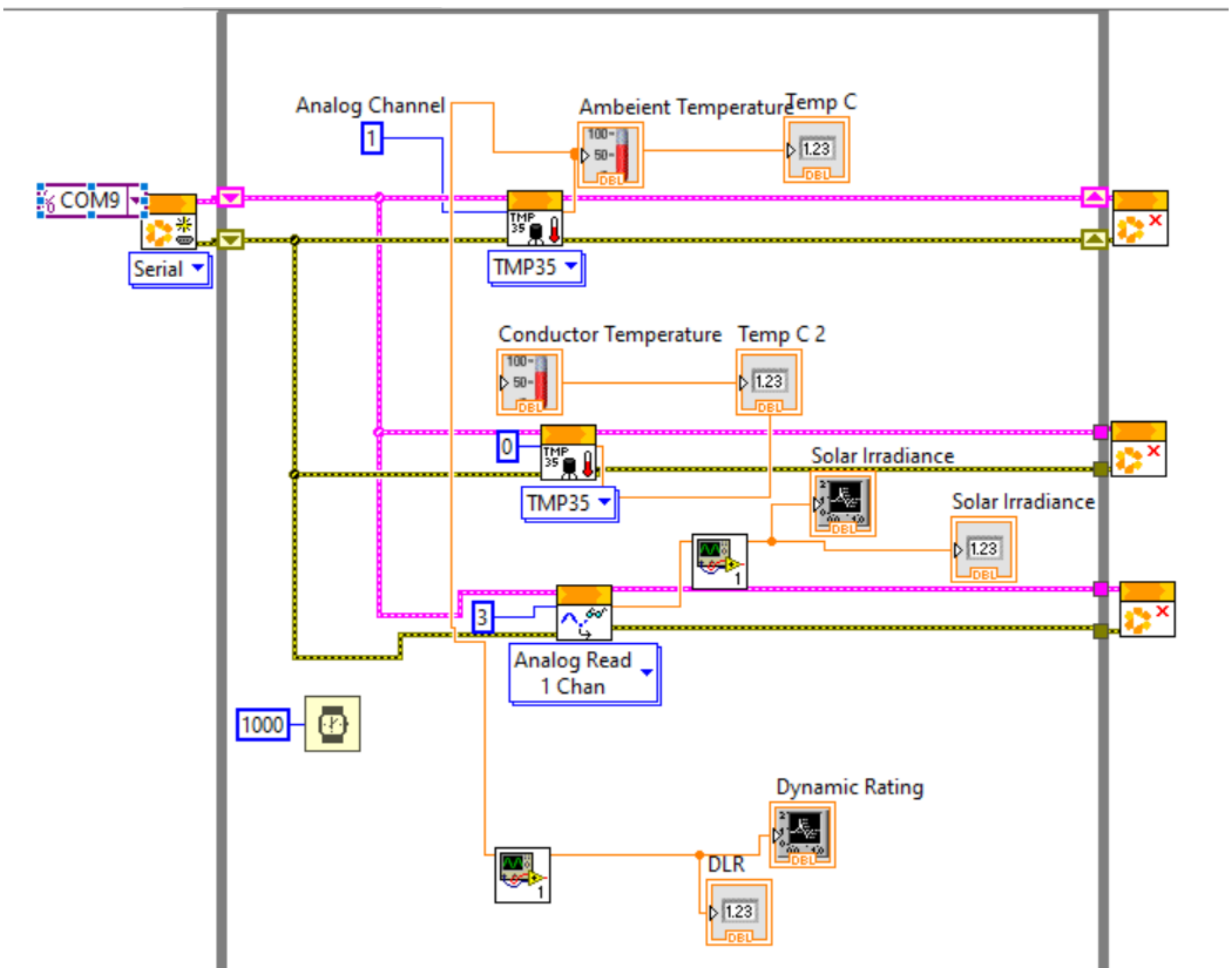

Figure 19. Programming of LabVIEW.

The box represents the loop which is set for 1 minute defined by the timer as 1000. Arduino Uno is used to interface between LabVIEW and sensors.

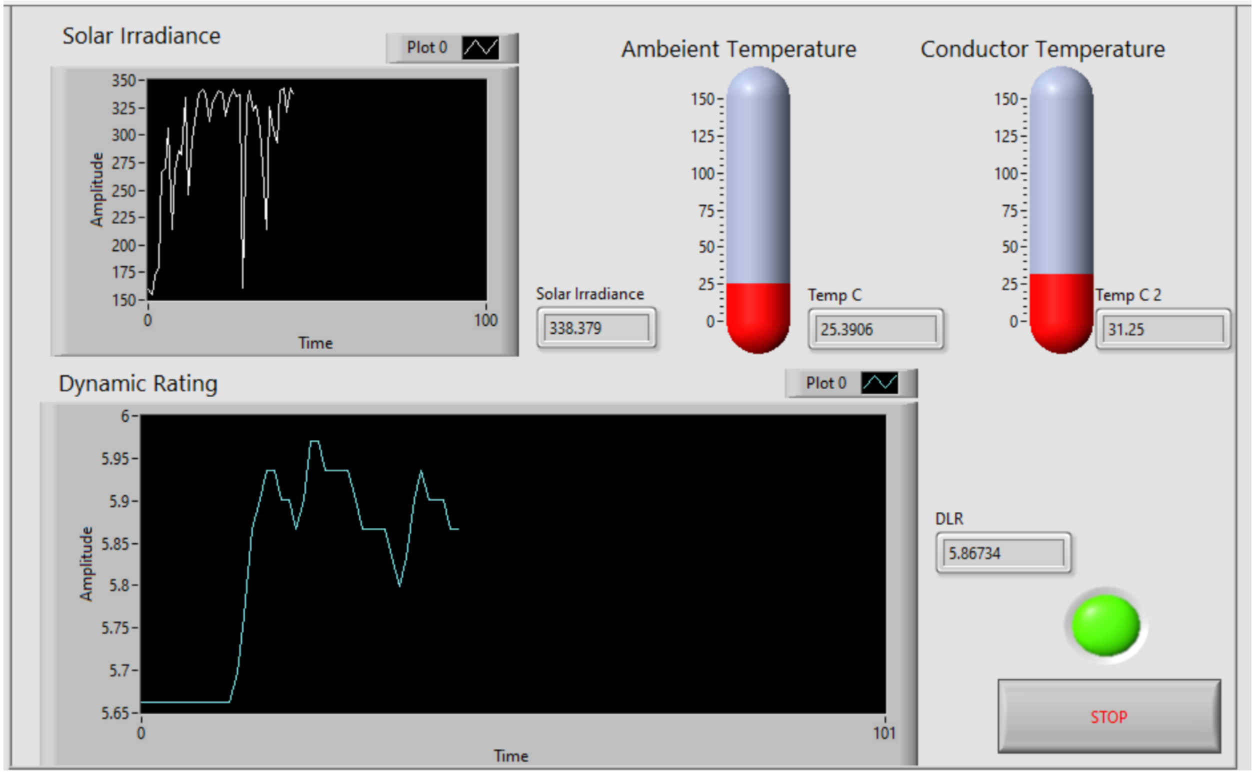

Figure 20. Graphical User Interface (GUI) of LabVIEW.

Figure 18 shows the GUI of the designed model. Here the data is taken at each second and displayed. The model is highly dependent upon wind velocity. This is not explicitly shown here but integrated in the data acquisition shown in the above results. This is a prototype model for the wire strand which acts as a proof of concept for overhead conductors and higher rating electric lines.

4.4 Summary of the Data Obtained from the Model

Using the above setup, the summary of data is shown in Table 6:

Table 6: SLR vs DLR at Different Environmental Conditions

Wire Strand	Wind (m/s2)	Irradiance (W/m2)	SLR	DLR
1	1.8	0	5.63	6.91
1	2.2	0	5.63	6.60
2	2.6	0	7.76	9.46
3	2.8	0	10.02	11
3	0	288.37	10.02	11.7
3	0	409.21	10.02	9.6

Table 6 data shows the dynamic line rating at different conditions with varying wind and irradiance. And the graph of the above ratings in Figure 19.

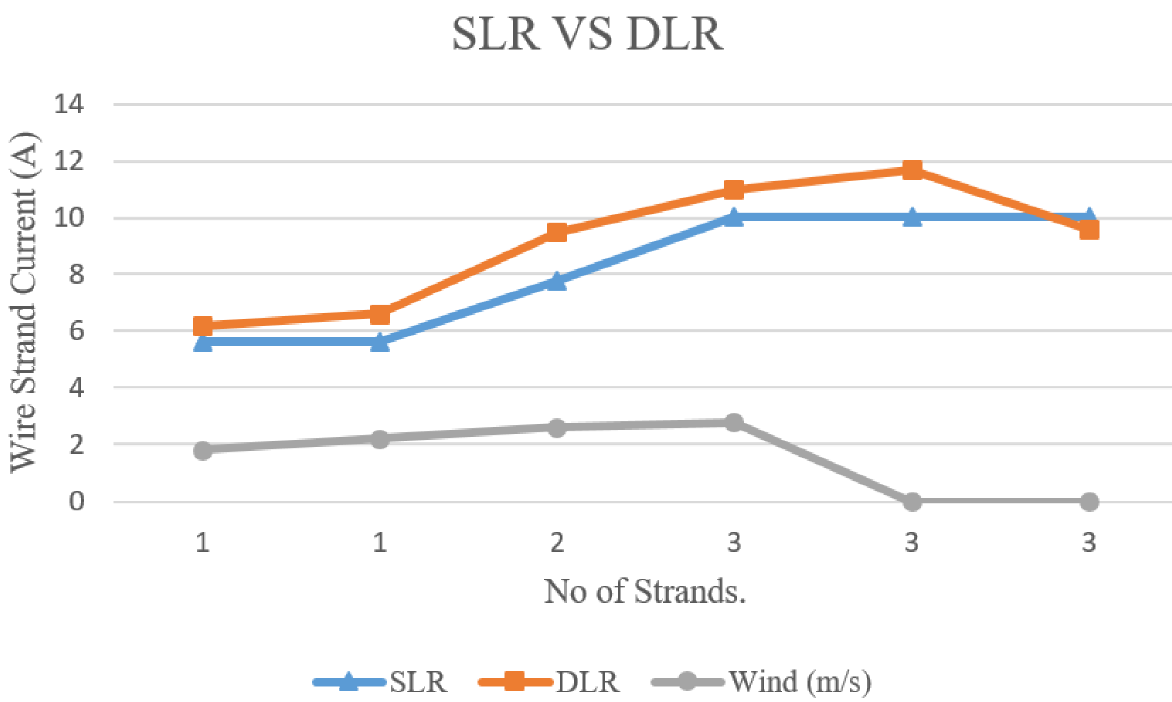

Figure 21. DLR VS SLR at different conditions.

Figure 19 shows the dynamic rating of the wire and its optimization potential. At the end the data overlaps which shows the DLR is below SLR which may be due to heater's heating effect used for increasing the irradiance. The static line varies because the number of strand changes and so does its rating. In this way the experimental setup data shows that the increase in wind speed increases the dynamic line rating while increase in irradiance decreases the dynamic rating of the wire.

CHAPTER 5: CONCLUSION & LIMITATIONS

Through the preliminary studies, it was verified that real-time thermal rating of overhead transmission lines is economically worthwhile, at least theoretically in every region as it can increase ampacity of a conductor by ~60% on average in cities like Dharan that have a relatively hot and windy climate such that convective heat transfer is much higher compared to regions with higher elevation. The transmission capability of any transmission line can therefore be improved, ranging from marginal to significant. The next phase of our project included design & fabrication of the instrumentation hardware required for experimental validation of real-time current ratings of a scaled down model of a transmission line subject to various natural as well as forcibly induced weather conditions. The first iteration of the hardware was improved upon to create a final prototype that can take temperature & irradiance data in real-time. Using this prototype, the ampacity strands of 1 sq.mm household conductor were tested, and real-time ampacity was determined by increasing the load on the wires. The real-time ampacity of the wire was that at which temperature reached 75°C. The wire had 10 strands and the wire's overall rating is ~50A, which means that each strand is rated at 5A. But from observations and analysis, it was found that this rating could be easily exceeded under certain cooling conditions and much higher loads could be supported.

The main limitation of this technology arises in hilly region-based transmission systems. In such systems, the real-time thermal rating of the conductor is limited to the real-time current carrying capacity of the critical span (the span where maximum temperature of the conductor occurs). In such cases, real-time thermal rating methods may give as less as 10% improvement in ampacity but in regions with large plains, this method introduces a significant improvement in the power carrying capacity of the transmission infrastructure.

With such technology, any transmission infrastructure's capacity can be enhanced, be it marginally or significantly, therefore decreasing the overall long-time upgradation costs of the overhead transmission network and making them more reliable. Suffice to say, real-time thermal rating of transmission lines makes the transmission system a living & breathing system.

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