Design and Analysis of 1

Abhishek Bansal 1

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Abstract

This is the second part of two-part series where the novel hybrid design of 1.5 MVA 25kV traction powered by 415 kW solar grid, capable of fully supporting the entire load of the section of the Govt./DISCOM railway feeder has been presented. In this second Part-II, the per-unit system, zero sequence network diagram, controller design, fault calculations (L-L, L-G), idmt relay settings, safety measures and guaranteed scheme of relay trip coordination with 1.5 MVA 132kV/25kV State utility owned feeder and proposed 1.5 MVA 25kV feeder has been explained. The whole proposal is also simulated and the results are in the dataset. railway distribution feeder along with various compensators is explained. The whole proposal I have left r&d, so will not correct update or complete papers. The earlier version of two parts, which was able to get saved from computer crash is uploaded.
Abstract—This is the second part of two-part series where the novel hybrid design of 1.5 MVA 25kV traction powered by 415 kW solar grid, capable of fully supporting the entire load of the section of the Govt./DISCOM railway feeder has been presented. In this second Part-II, the per-unit system, zero sequence network diagram, controller design, fault calculations (L-L, L-G), idmt relay settings, safety measures and guaranteed scheme of relay trip coordination with 1.5 MVA 132kV/25kV State utility owned feeder and proposed 1.5 MVA 25kV feeder has been explained. The whole proposal is also simulated and the results are in the dataset.

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Index Terms—railway system, rail transportation, rail transportation control systems, protective relaying, electrification, 25kV, centralized-decentralized control, traction substation, power quality, energy conservation, 160km/hr.

I. INTRODUCTION

This is the second part of the proposal design (for innovation challenge) proposed by the author, which is modified here with more explanation than was initially submitted in the small concept paper to Ministry of Railways, Govt. of India in the year 2017.

This elaborates the hybrid design on known concepts,

Proposed Controller & Distribution Feeder Design

The numbering of the figures is in continuation w.r.t. Part-I, so as to easily referred by it.

The plan of the paper is as follows: In the Section II, the design of the solar power plant and the generation of rated power of 415 kW producing approx. 880 kWh per day has been explained. This section in its subsections also explain In the Section III, the secure and safe guaranteed connection to railway distribution feeder on the 132 kV hybrid transmission is explained.

monitoring

In the Section IV, the controller ensuring this being discussed.

In the Section V, the conclusion and future work is summarized.

II. SLD

The complete single line diagram (SLD) as explained in Part-I is shown in Fig., and would be subjected to faults to analyze the robustness of the design

The SLD of the power plant is shown for the sake of completion purposes and as concluded from Part- I, that the solar plant would be providing 1.5 MVA of power. The faults in the generation or other faults which could eventually destroy the complete power plant (due to internal resources) is beyond the scope of these paper series. So, the analysis of faults and protection schemes would be considered w.r.t. to this feeder transmission line starting at ‘AC Disconnect 1’ as shown in Fig. 1 in green line, marked with ‘Starting Point of Fault Analysis’ till the 132kv/25kv feeder which

III. PU SYSTEM

the per-unit system,
IV. ZERO SEQUENCE NETWORK DIAGRAM

V. RELAYS USED

The controller has many functions - to perform islanding, harmonic traction voltage between 25 kV and 27.5kV to detect if the voltage is frequency between 48.5 Hz and 51.5Hz. Individual harmonic distortion (Vn) and total harmonic voltage distortion (Vt) at the point of supply shall not exceed 1% and 3% respectively.

VI. IDMT RELAY SETTINGS

Corona discharge time graded sequential operation controller design, safety measures and guaranteed scheme of

VII. RELIABILITY

As the traction line is designed to be powered by either 66kV/25kV or 415V/25kV, the design reliability, \( R_d \) is determined using concepts of ‘Reliability Engg’ [9].

\[
R_d = 1 - (1 - R_1)(1 - R_2) = P(T_1^c)P(T_2^c) = P(T_1 \cap T_2^c)
\]

where \( R_1 \) is unreliability of \( T_1 \), \( R_2 \) is unreliability of \( T_2^c \). \( T_1 \) is the event that transmission line 66kV/25kV fails and is the complementary of event when \( T_1 \) transmission is successful, \( T_2^c \) is the event that transmission line from the solar grid 415V/25kV fails and is the complementary of event when \( T_2 \) transmission is successful.

Let \( \lambda_1 \) is the failure rate of \( T_1 \) and \( \lambda_2 \) is the failure rate of \( T_2 \), \( U_1 \) is the unavailability of \( T_1 \), \( U_2 \) is the unavailability of \( T_2 \), \( \bar{f}_1 \) is the average frequency of failure of \( T_1 \), \( \bar{f}_2 \) is the average frequency of failure of \( T_2 \), \( \bar{r}_1 \) is the mean time for down transmission of \( T_1 \) to up, \( \bar{r}_2 \) is the mean time for down transmission of \( T_2 \) to up.

\[
R_d(t) = e^{-\lambda_1 t} + e^{-\lambda_2 t} - e^{-(\lambda_1 + \lambda_2)t} \quad \therefore (R_d(t) = 1 - (1 - e^{-\lambda_1 t})(1 - e^{-\lambda_2 t}))
\]

This is sum of exponentials rather than a simple single exponential because failure rate is the variable function of the operating time (even though the failure rate and mean time between failures is constant).

In the event of unavailability of solar grid power, whether due to repair or maintenance, the equations for average frequency of complete design failure, \( \bar{f}_d \) and average time to failure or operation time or uptime, \( \bar{t}_d \) are given as

\[
\bar{f}_d = U_2 \bar{f}_1 + U_1 \bar{f}_2
\]

\[
\bar{t}_d = \frac{\lambda_2 \bar{r}_2}{1 + \lambda_2 \bar{r}_2} = \frac{\lambda_1 \bar{r}_1 + \lambda_2 \bar{r}_2}{\lambda_1 \lambda_2 (\bar{r}_1 + \bar{r}_2)}
\]

A. Failure Possibility Calculations

Following are expected failure & reliability calculations. Let one fault per km is expected to be on the transmission line every two months, thus, in total six faults per km over a period of 1 year, and the repair or the uptime is 7 hours per fault. Let the annual cable termination fault be 0.45 per cable termination and its repair uptime is 6 hours. Using the formulae [9]

(i) Failure rate of design, \( \lambda_d \) = 20 \times 6 + 2(0.40)/100 = 120.008 faults per year
(ii) Average restoration time, \( \bar{r}_d = 7 + 2(6) = 19 \text{ h} \)

\[
\bar{r}_d = \frac{(20 \times 6) \times 7 + (2(0.40)/100 \times 6)}{120.008} = 6.999933338 \text{ h.}
\]

Annual mean time to failure = 8760 - 6.999933338 = 8753.000066662 h.

\[
\therefore U_d = \frac{6.999933338/(8753.000066662 + 6.999933338)}{0.000790979} = 0.0799%.
\]

Availability of design = 0.999200921 or 99.92%.
CONCLUSION AND FUTURE WORK

This paper can motivate manufacturers to invest which otherwise could help them to prepare in the event of grid failure or other emergency disaster situations. The booster transformer can be replaced with tap-changing transformer.

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REFERENCES


Abhishek Bansal The author was born on 6 Feb 1983 in Delhi, India and had been an amateur scholar, fully self taught, had self studied various engineering & mathematical fields/specializations, & medical sciences. He had been working as an independent researcher and as a practicing professional engineer for over 18 years with many industries, with last designation held as Sr. Electronics Design Engineer (Sr. Manager - R&D) in a pvt company. The dataport of the author can be accessed at https://ieee-dataport.org/authors/abhishek-bansal and his ORCiD identification number is 0000-0002-2572-9004.