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Research Article

The determination of the running reliability of the system with the method of polynomial regression for electricity transmission lines

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Abstract

One of the most essential data of the social and economic development accepted all around the world is energy. The reasons such as the rapidity of the urbanization and industrialization and rapid increase in population cause to the continuous and indispensable increase in the demand for energy. While the demand for electricity energy is so high, what is important in terms of the user is the submission of the continuous and qualified energy to their own usage. In this study, the failures and power transformer failures occurring in Turkey electricity transmission system have been detected as hourly, monthly and annually and in this way; with the use of these data, the reasons for the failures have been examined and suggestions for solutions have been studied and it has provided opportunities for the conduction of preventive maintenance and repair works in the future. When the failure numbers of 380 kV lines have been examined, it is seen that some lines paint a very negative picture. When the failing lines have been monthly examined, it is seen that there is an accumulation in terms of failure in April-May and August-September periods. By means of this study; the failures occurring in the energy transmission lines have been classified on the basis of hour, month and year and the running reliability of the system in the transmission lines to be established in the future has been determined.

Keywords: ***Transmission Lines, Maintenance-Repair In The Transmission Lines, Short Circuit Analysis, Power Analysis***

1. Introduction

The line that connects the production point of electricity energy to its consumption point is defined as energy transmission line. While projecting the energy transmission lines, they are designed according to the convenient voltage level and cable section by taking the parameters such as the amount of the energy to be carried and the distance to the destination point into consideration. The voltage levels and cable sections selected at the stage of design have been determined with the international standards. The energy transmission lines have been connected to one another due to the variation and increase in the energy consumption and production points. The main purpose of such a connection (bonding) is to connect the production points to one another and use them as if there were a single production point.

The system that occurs with the connection of two energy transmission lines in a point by starting from another point is called as ring system. The usage advantage of the ring system is that it allows the feeding of the consumption point taking place on it from more than one place and in this way; the affection of other consumption places due to a failure in one of the consumption centers has been prevented. The energy transmission system in Turkey provides energy transmission to the consumption centers at two voltage levels as 380 kV and 154 kV. The use of 66kV lines has been eliminated and the existent ones are replaced with the new ones. The distribution lines used in our country have been standardized to 33kV voltage level. When the electricity transmission lines are examined, the failures faced as the most are the phase-phase, phase-soil and insulator failures. The failures stemming from the insulators generally occur due to the contamination of the insulator [1, 6].

The energy transmission lines are established by respecting the following process steps.

- 1/2500 scaled map of the energy transmission line planned to be established between the selected two points is supplied and the route on the detected two points is determined on the map. Attention should be paid to the fact that this determined route should be the closest distance connecting these two selected points.
- Concrete piles are penetrated in the field on the points determined in the map and in this way, the field profile of the energy transmission line is constructed.
- At what point the poles shall be erected in the field whose profile has been constructed is signed, the poles are selected according to the structure of the field, strength of the poles and the safety distance and the processes are continued.
- The line is completed by laying transmission cable to the pole whose lower and upper assembly have been completed.

Many studies have been done both in our country and in the world to contribute energy productivity by using

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smart and micro networks. These studies are done in the form sometimes as solving problems encountered in energy transmission lines with new methods and sometimes as productivity directly [9-12].

2. The use of multivariate non-linear regression with 3D surface fitting algorithm

In the event that one of the emphasized variables is dependent (y) and the other one is independent (x), the expression of y as a function of x is called as regression. The analysis examining the relation between dependent variable and independent variable is expressed as regression analysis. Regression analysis is a kind of analysis that provides us with the understanding of the cause and effect relation between the variables. If there is one ea. dependent variable and more than one independent variable, this situation is called as multiple regression. The relation between two variables could be linear, exponential, logarithmic and etc. In this study; surface fitting algorithms have been benefited and a function being 2nd order polynomial has been used and the general status of the equation is given with equity (Equation 1).

$$Z = F(x,y) = p_{00} + p_{10} * x + p_{01} * y + p_{20} * x^2 + p_{11} * x * y + p_{02} * y^2 \quad (1)$$

In equation (1); $p_{00}, p_{01}, p_{02}, p_{10}, p_{11}, p_{20}$ are the coefficients determined with the surface fitting algorithms. The data shall be examined 3-dimensionally and it is displayed in Figure 1 as template.

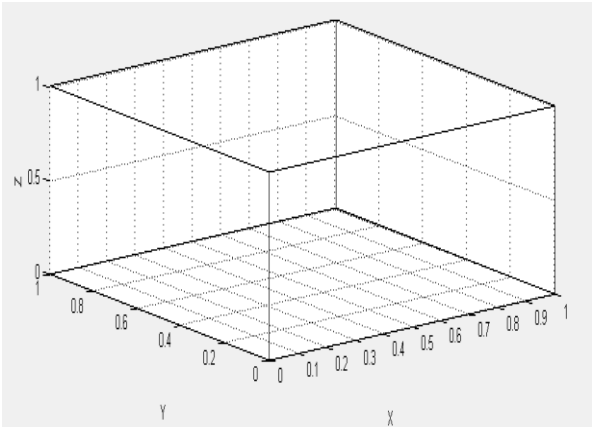

Figure 1. Draft for 3-dimensional examination of the data

3. The examination of the electricity transmission line failures

3.1 The examination of the failures of all the electricity transmission line system

In this section; the transmission line failures occurring in Turkey for the last six years have been classified in detailed way. Such a classification of the occurring failures has an importance in that at what frequency the personnel to carry out the protective maintenance and repair works encounters with the transmission line failures. In this section of the study, the transmission lines in Turkey have been grouped according to their voltage levels and the days in which the line shall run have been determined with the help of the surface fitting algorithm. Detailing the failures according to the data belonging to the last six years has a great importance in terms of detecting the running reliability of the system in the preventive maintenance and repair works [7, 8].

Table 1. Electricity transmission line failures in Turkey

Years	Total Line Length	Failure Number	Line Active (Day)	Failure Index
2009	51.451.130	4.048	351,14	8,18
2010	52.539.263	4.404	354,45	8,63
2011	54.267.422	4.636	357,12	8,73
2012	54.826.254	4.517	359,85	8,38
2013	57.377.076	3.999	355,38	7,16
2014	59.706.994	4.693	354,48	8,09

When surface fitting algorithm has been applied to the data specified in Table 1, the situation in Figure 2 shall occur. The increase of the failures mentioned in Table-1 in number shall seriously decrease the productivity in the industrial facilities [2].

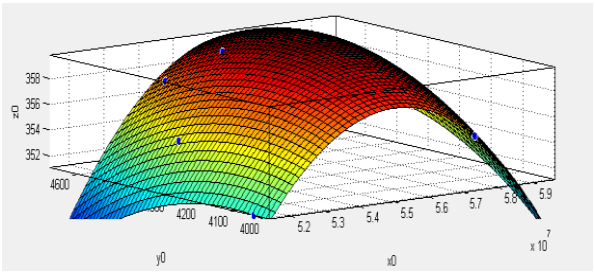

Figure 2. The application of 3-dimensional surface fitting algorithm to all the transmission line

The total line length is expressed as x0, number of failure is expressed as y0 and the number of days in which the line has run is expressed as z0 in Figure 2. The coefficients attained after the application of surface algorithm are given below.

p00 = -1211; p10 = 5.201e-005; p01 = 0.05284; p20 = -5.706e-013; p11 = 2.712e-009;
p02 = -2.333e-005.

When these attained coefficients are inserted to their places in the equation (1), the estimated values shall be reached. The comparison of the estimated value to the real value is given in the graphics in Figure 3.

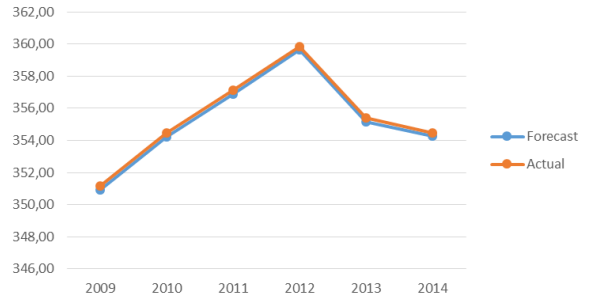

Figure 3. Number of days in which the line has run

When Figure 3 is carefully examined, it shall be observed that the real value and the estimated value have the

results that are so close to each other after the application of the surface fitting algorithm. The numerical data regarding the estimated and real values are given in Table 2.

Table 2. The numerical data showing the number of days in which the line has run regarding the real value and estimated value

Years	Estimated	Real
2009	341,03	340,80
2010	346,19	345,96
2011	354,55	354,30
2012	359,28	359,05
2013	346,54	346,31
2014	346,08	345,84

3.2 The examination of the electricity transmission line system failures at 380 kV voltage level

In this section; the transmission line failures occurring in Turkey in the last 6 years have been classified in detail as monthly and hourly by taking 380 kV voltage level into consideration.

Table 3. 380 kV electricity transmission line failures in Turkey

Years	Total Line Length	Failure Number	Line Active (Day)	Failure Index
2009	15.133.044	1.055	340,8	7,47
2010	15.955.365	1.264	345,96	8,36
2011	16.691.201	1.577	354,3	9,73
2012	16.733.421	1.215	359,05	7,4
2013	17.871.957	1.001	346,31	5,9
2014	18.543.685	1.231	345,84	7,01

When the surface fitting algorithm is applied to the data specified in Table 3, the situation in Figure 4 shall occur.

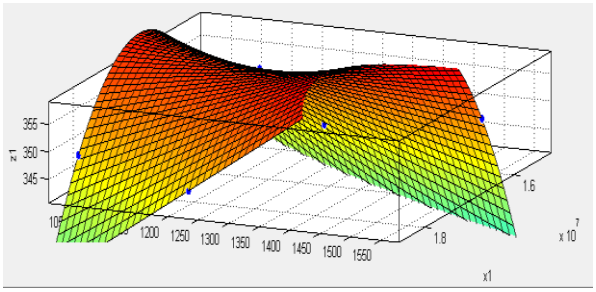

Figure 4. The application of 3-dimensional surface fitting algorithm to 380 kV transmission line

In Figure 4; the total line length is expressed as x1, number of failure is expressed as y1 and the number of days in which the line has run is expressed as z1. The coefficients attained after the application of surface algorithm are given below.

p00 = -1064; p10 = 0.0002262; p01 = -0.8606; p20 = -8.383e-012; p11 = 5.063e-008;
p02 = 1.186e-006

When these attained coefficients are inserted to their places in the equation (1), the estimated values shall be reached. The comparison of the estimated value to the real value is given in the graphics in Figure 5.

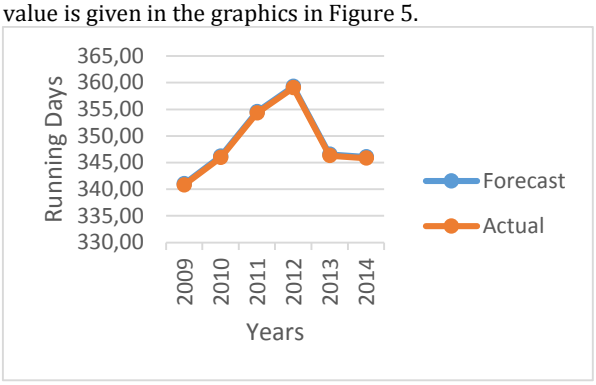

Figure 5. The number of days in which the line is active

When Figure 5 is carefully examined, it shall be observed that the real value and the estimated value have the results that are so close to each other after the application of the surface fitting algorithm. The numerical data regarding the estimated and real values are given in Table 4.

Table 4. The numerical data showing the number of days in which the line has run regarding the real value and estimated value

Years	Estimated	Real
2009	341,03	340,8
2010	346,19	345,96
2011	354,55	354,3
2012	359,28	359,05
2013	346,54	346,31
2014	346,08	345,84

In terms of providing benefits for the personnel to perform the maintenance and repair, Table 5 has been submitted to the attention of the users for the purpose of determining at which months the failures are observed more frequently.

Table 5. Monthly distribution of the failures occurring in 380 kV electricity transmission lines

Months	2009	2010	2011	2012	2013	2014
Jan	18	112	93	107	65	51
Feb	33	92	78	108	49	27
Mar	58	136	140	47	73	78
Apr	174	185	270	196	162	194
May	131	78	209	180	209	178
June	89	103	95	82	88	109
July	85	61	100	91	51	102
August	85	69	117	90	78	95
Sept	111	93	275	100	82	153
Oct	102	109	113	114	71	106
Nov	95	70	47	38	25	64
Dec	74	156	40	62	48	74

When Table 5 is examined, it shall be observed that the highest number of failure occurs in April-May and August-September periods in 380 kV electricity transmission lines.

The data belonging to the last 6 years have not only been monthly classified, they have also been classified as hourly for a more detailed analysis. The hourly data are given in Table 6.

Table 6. The hourly analysis of the failures occurring in 380 kV transmission lines in the last 6 years

Hours	2009	2010	2011	2012	2013	2014	Number of Failure
00-03	183	220	288	200	151	240	240
03-06	337	406	610	395	354	399	399
06-09	126	204	217	156	113	162	162
09-12	46	69	53	64	50	54	54
12-15	66	71	70	98	79	93	93
15-18	65	76	90	91	97	59	59
18-21	77	86	84	80	51	85	85
21-24	155	132	165	131	103	139	139

When Table 6 is examined, it shall be seen that the highest number of failure occurs between the hours 03-06 in 380 kV electricity transmission lines.

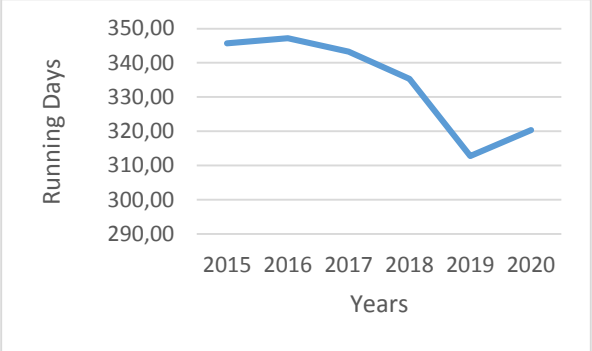

Figure 6. Graphical display of the days in which the line shall run for the next 6 years

4. Conclusion

The failures occurring in the electricity transmission lines and the days in which the line has stayed open within the years due to these failures have been classified in detail with the use of the surface algorithm. Because the demand for energy consumption shall increase in the next years, the institutions liable to establish electricity transmission line system shall establish new electricity power plants and transmission lines for the purpose of meeting the demand of the energy to be consumed. In this study; multiple non-linear regression analysis has been used by applying to the surface fitting algorithm while determining the analysis of the previous data and the number of the days in which the line shall run for the next 6 years; and artificial neural networks could also be benefited when there are more data .

When 380 kV and 154 kV line failures have been hourly examined, it is observed that there is a clear accumulation between 03:00 – 06:00. A total of 1231 failures have occurred from 380 kV line in 2014 and 1210 ea. (98%) of them are temporary and 21 ea. (2%) of them are permanent. When the failures in 2014 have been assessed on 154 kV transmission system, a total of 3383 failures have occurred and 3228 ea. (95%) of them are temporary and 155 ea. (5%) of them are permanent type failures. The highest number of failures in the power transformers has occurred in summer months. 16 ea. (1%) of 1296 failures occurring in 2014 have occurred as permanent transformer failure due to the power transformer opening.

Such a detailed classification of the encountered failures has a great importance in terms of the personnel that shall perform the preventive maintenance and repair works. The results in Figure 6 shall be attained when the results attained from the surface fitting algorithm are applied to the transmission lines whose construction is planned within the next 6 years.

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