Application of artificial intelligence in early fault detection of transmission line-a case study in India

Prashant P. Mawle[1], Gunwant A. Dhomane[2], Prakash G. Burade[3]
[1]Department of Electrical Engineering, Government College of Engineering, Chandrapur, India
[2]Department of Electrical Engineering, Government College of Engineering, Amravati, India
[3]Department of Electrical Engineering, Sandip University, Nasik, India

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ABSTRACT

Reliable energy is ensured by the power quality, safety and security. For reliability and economic growth of transmission utilities, it is necessary to maintain continuity of supply, which is challenging under deregulated system. It is essential for utilities to conduct regular maintenance of transmission lines before supply interrupts. To protect line from fault, it is necessary to detect fault on line, its classification and location at the earliest. Various smart techniques along with application of artificial intelligence (AI) in power system are under investigation. This paper tries to find solution by identifying practical common faults occurred on transmission lines, and also suggests the suitable maintenance methodology. It uses the artificial neural network (ANN) method and live line maintenance technique (LLMT) for pre identification of a fault and subsequent predictive maintenance. Paper compares results of combination of ANN with LLMT and cold line maintenance technique (CLMT). Comparison of statistical analysis shows combine model of ANN and LLMT results in minimize outage time, failure rate which can improve system availability and increases revenue.

Corresponding Author:

Prashant P. Mawle
Department of Electrical Engineering, Government College of Engineering
Chandrapur, India
Email: ppmawle1@gmail.com

1. INTRODUCTION

Quality, safety and uninterrupted energy supply can be maintained by regular maintenance of transmission lines. To apply maintenance there is a need to detect fault situations at early, detect the reason of occurrence, reasons of transmission equipment failure and to apply suitable maintenance required. Maintenance activities needs to be pre-scheduled in advance for all types of maintenance using ON line maintenance technique or Off-line maintenance technique. A survey said that for the year 2020, there were approximate 1,160 faults in the Indian grid, in that 65% of faults accounting on transmission lines; 20% faults related to the transformer equipment, 10% faults due to bus bar and other equipment in substation and 5% faults due to other reasons [1]. Transmission system condition study consists of age, stress condition, failure mode, safety, and working environment condition. It is proposed to use artificial intelligence (AI) technology to detect fault at early stage. Two types of method based on records driven and facts driven are applied. Record driven method depends on available data, learning and regression technique, it uses training data to learn the patterns. The knowledge driven method uses expert's opinion for simulation and diagnostic [2]. Fault finding method for high-voltage transmission lines with three fed (TFHVTLs) is available. Testing current signals taken from one end of TFHVTL measuring system. Analysis technique named wavelet multi-resolution is used to purify these current signals [3]. Combination of an integrated framework for location of fault and its classification proposed extreme learning machine summation-wavelet (SW-ELM) algorithm. For diagnosis of fault, summation-gaussian extreme learning machine (ELM-SG), is applied. ELM-SG is self-learning and extended version of SW-ELM, it is easy to operate [4]. Correct action of maintenance depends on reason of line interrupts, damage equipment, location, line loading and risk in maintenance [5]. In Indian transmission lines fault includes interruption due to flashover of insulator, fire in forest, over-voltages due to lightning, flash-over from transients to normal power frequency voltage, wind, moving objects, outside environmental force destruction, barriers due to trees, and birds.

There are severe faults under which maintenance needs to be applied after taking breakdown such maintenance is called CLMT. There are some faults under which maintenance can be applied without taking any outage such maintenance is called live line maintenance technique (LLMT). To improve maintenance, regular testing needs to carry, assure the testing data accuracy, fixing the responsibility and increase the training. It is suggested to maintain proper earthing and earth resistance as per requirements [6]. Check lines for correct right of way (ROW), insulators insulation property, physical condition of insulators and connectors, connection of insulator on complete line and control devices of insulators [7]. Live-work technologies have advantages as no power loss, reduces penalties during downtime, the problem can be attended immediately, avoids emergency outages, which helps to minimize event risk and reducing switching cycles of switchgears. Live line maintenance needs less manpower and less time required for maintenance as compared to the cold line method, this gives economic benefits and postponement of life to apparatus gives added ways to improve live line technologies [2], [8].

Proposed maintenance applied AI techniques in fault-finding process with live line maintenance. Some transmission organizations adapting fault locating devices by global information systems (GIS) for fault location in power quality measurement systems. Expert system techniques (XPS), fuzzy logic systems (FLS) and artificial neural networks (ANN) are dealing with information in planning the uncertainties in transmission system; this is a challenge for system planners [2]. Many utilities have insufficient statistical data, but engineers normally predict the range of uncertainty data by representing the load modeling and outage parameters of component system using above techniques [9]. For planning transmission systems models become a necessary supplement as selection of probabilistic, models are required to consider with both types of uncertainty of input details with all cases. Fuzziness and randomness are two types of power systems uncertainty. Model of probabilistic can be applied to randomness. Fuzzy models applicable method suitable to express indecision during peak load forecasting. To addresses the issues during load forecasting and data outages various artificial models are used. Analogous theories of modeling may be used to indecisions of different information such as equipment factors and grades which impacted by different environmental parameters [1], [10].

This paper explains the model and steps for the probability calculations. Flow chart explains the step wise procedure to identify and locate the fault using ANN tool. A probability analysis for ten no of various faults are shown. Using LLMT for line to ground fault, calculation shows reduction in outage time and power loss compared with outage maintenance by CLMT. Paper shows analysis for given fault condition as input method and maintenance results output data and an application of ANN method.

2. TRANSMISSION LINE FAULT ANALYSIS METHOD

For fault analysis system must continuously record and measure energy parameters like current, voltage, frequency, power factor, reactive power kilovolt ampere reactive (KVAR) and active power kW at all terminals. Technical operating and maintenance persons can measure parameters of energy systems, consumption for heavy electrical loads connected in that area, observe start up time, efficiency and economy measure of electrical equipment [11]. Recorded information is used to assess system reliability, calculate profit of reliability due to maintenance of each section, produce maintenance ranking order by applying benefit/cost ratio index [1], [7], [12]. Predictive maintenance (PdM) imparts condition monitoring and asset management as keys [13]. Transmission system classification depends upon component parameter, position of component placed, type of faults, reasons for fault occurrences, reasons of equipment failure and types of maintenance required [14]. Transmission line of 400 kV between Koradi to Bhusawal of Maharashtra state, India is presented as Figure 1, for case study. Data of total numbers of faults that regularly occurred in the year 2020 are taken for study.

2.1. State enumeration method and Monte Carlo simulation

State enumeration is efficient when component failures probabilities are very minor and complex operating conditions are neglected [3], [15]. An organized methodology for maintenance management is reliability centered maintenance (RCM) with objective to provide proper preventive maintenance (PM) preparation to get maintenance with economy and intrinsic reliability [8], [16]. Monte Carlo simulation and method of state enumeration are used for larger severe events under complex condition of operation.

When there is involvement of larger severe events and complex operating conditions, the unit of the U (unavailability)-forced outage rate (FOR) is kWh or MWh/year or outages/year. μ-repair rate is reciprocal of repair time, it is repairs per year. λ-failure rate (failures/year)=1/d. *r*-repair time (repairs/year), *r*=MTTR/8760 in the unit of years. μ=1/mean time to repair=1/r. *r*-mean time to repair in hours (MTTR), or repair time *r* (or outage rate λ) are in hours/outage. *d*-mean time to failure in hours (MTTF), *d*=MTTF/8760 in the unit of years. *f*-average failure of frequency (failures/year) or outages/year is unit of frequency (outage).

$$f = \frac{1}{d + r} \tag{1}$$

The parameters of systems *U* unavailability identified by using *f* frequency outage and *r* repair time.

$$U = \frac{r.f}{8760} \tag{2}$$

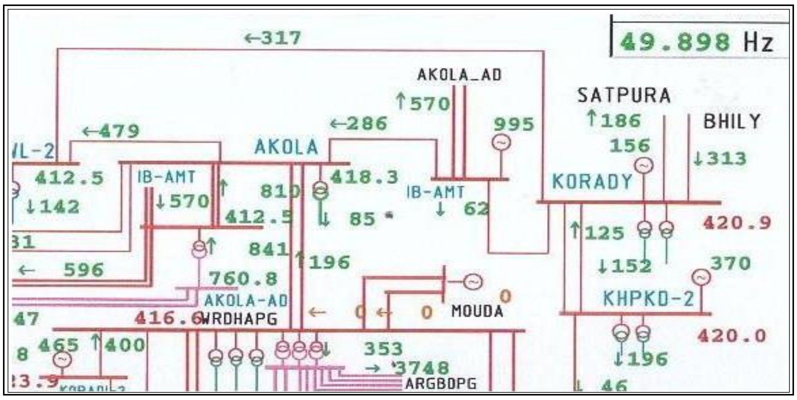


Figure 1. Grid-connected of state transmission company

2.2. Semi forced outage

Markov method is used for complex operating conditions. Markov method is used to apply LLMT for given model. Figure 2 shows semi-forced outage state space diagram of a state-space model for an outage of semi-enforced system, which refers to case in which a physical problem of a systems parameter which cause system outage applying to postponement of time which can rescheduled depends on an involuntary cause [3], [15], [17].

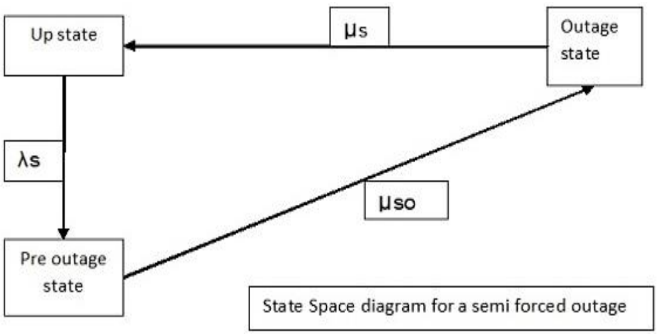


Figure 2. Semi-forced outage state space diagram

$$Psu = \frac{\mu s\ \mu so}{\lambda s\ \mu s + \lambda s\ \mu so + \mu s\ \mu so} \tag{3}$$

$$\text{Psp} = \frac{\lambda s\ \mu s}{\lambda s\ \mu s + \lambda s\ \mu so + \mu s\ \mu so} \quad (4)$$

$$\text{Pso} = \frac{\lambda s\ \mu so}{\lambda s\ \mu s + \lambda s\ \mu so + \mu s\ \mu so} \quad (5)$$

Fs is frequency of the problem taking place (occurrences/year).

$$Fs = \frac{\lambda s\ \mu s\ \mu so}{\lambda s\ \mu s + \lambda s\ \mu so + \mu s\ \mu so}$$

Where, λs - rate of transition state between up state to preoutage state, μs - rate of repair state is reciprocal of time to repair state, μso - rate of transition state between pre outage state to outage state, *Psu* - probabilities of the upstate, *Psp* - probabilities pre outage state, *Pso* - probabilities outage state.

2.3. ANN technique

Fault location from both the ends of the line can be found using AI. To find out the location feedforward backpropagation neural networks can be used for training purposes on transmission model. To train the model data of faulty insulator detection using proportional integral and derivative (PID) test conducted on 400 KV Koradi-Bhusawal line is used. Transmission line model for individual phase fault of three phases were computer-generated for 350 km line length with intervals of 5 km [4], [18], [19]. ANN gives accurate pattern recognition, which is proposed by researcher to use in various applications of power system, decision making under fault condition, relaying and for signal processing [20]. Collected real time faults and corresponding data are used for testing and training the model. After testing data and training data, model can be used for transmission line fault incidents. After identifying fault, fault classification can be done into different categories as per faulty phases.

3. RESEARCH METHOD FOR FAULT FINDING

For identification of transmission system faults, the significant general steps are defining the system, define failure criteria, make suitable assumptions, prepare system model, carry out failure effect analysis, evaluate reliability indices, analyze the result, and prepare reliability improvement plan. The faults in the proposed transmission system are determined by the implementation of developed procedure [2], [7], [13], [14], [19] as shown in Figure 3. The proposed fault finding algorithm uses the nomenclature as-current flow through the conductor (I), transmitting voltage (V), apparent power (S), active power (P), reactive power (Q), frequency (f) (50 Hz), power factor (φ), load angle (δ), active power supplied per phase-Pa, Pb, Pc, reactive power supplied per phase-Qa, Qb, Qc, apparent power supplied per phase-Sa, Sb, Sc, voltage per phase-Va, Vb, Vc, current per phase-Ia, Ib, Ic, and IPF-pre fault condition current [4], [6].

Increases transmission systems load ability by knowing real time data of bus voltages, currents and separation of angle between buses. This gives resources utilization in better way [19]. Maintenance planning is critical important for deregulated supply as transmission system having aging hardware and components. This maintenance planning and optimizing decision can save cost. Reliability centered maintenance (RCM) method is used in this method [21]. Advanced technologies are developed in recent, such as anchors replacement, installing monitoring systems, lightning arresters, installation surveillance systems on line arresters, and replacement of earth wire [22]. The proposed procedure utilizes symmetrical component analysis to determine fault current, fault impedance, impedance angle and positive-sequence impedance. Flow charts show the step wise method for fault identification and decision for correct maintenance using LLMT by considering various parameters like reasons for faults, proper procedure, maintenance safety and security. Follow procedure for calculation of transmission system availability-for each voltage level-calculate availability and declare it separately, alternating current (AC) transmission lines-consider each circuit as one element of the AC transmission line [23]. OHLs maintenance projects doing all types of work like overlaying [11], [23]. There are some faults that can be predicted at pre outage stage for which live line maintenance can be applied (LLMT). To improve LLMT, working environment and safety features. refresher training can be provided from experienced utilities with expertise sharing, continuously upgraded technical skills and knowledge [24]. For different reasons of fault Table 1 shows common types of faults occurred in a month as outage, unit loss and type of possible maintenance applied on a given line. Graphical representation of possible outages, power loss, units and revenue loss in rupees can be saved under different types faults by using LLMT. LLMT can be applied by standard procedures created on best practices and international norms as documented by authorities like International Electrotechnical Commission (IEC), Institute of Electrical and Electronic Engineers (IEEE) and work by Conference Internationale des Grandes Reseaux Electriques (CIGRE) and Electric Power Research Institute (EPRI) [24].

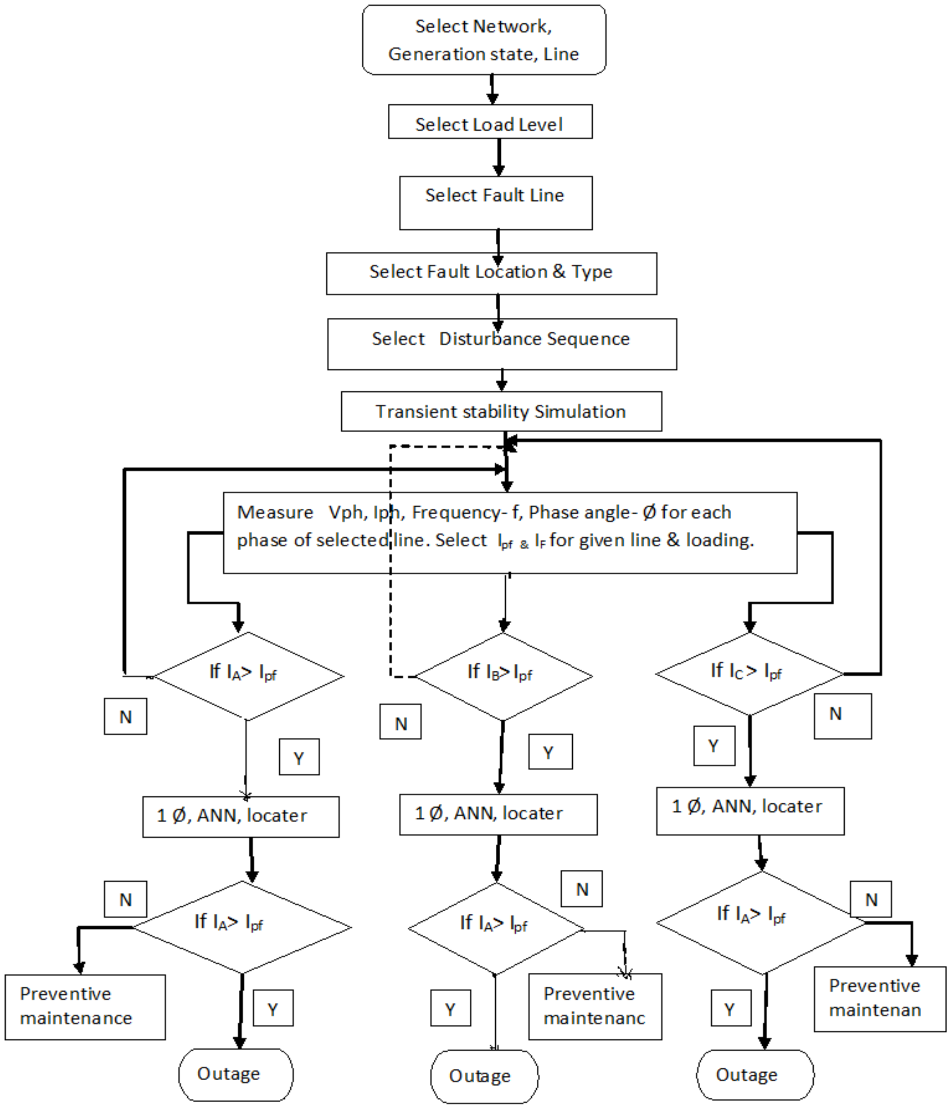


Figure 3. The developed procedure for fault finding

Table 1. Common fault occurred and maintenance applied

Reason	Outage (Hr)	PL (MW)	Loss in MWh	Revenue Loss Rs. (Lakh)	Remedial Measure	Maintenance Applied
220 kV Jumper snapped	2.4	1644	3945.6	197.28	Jumper repaired	CLMT
400 kV line tripping	3.1	1364	4228.4	211.42	Line restores	LLMT
Load failure on 400 kV lines	0.3	1337	401.1	200.55	Line reloads and restore	LLMT
Line tripped on R-Y-N fault over load	1.2	1865	2238	111.9	Removed overload and short circuit	CLMT
Tripped due to earth fault	1.4	1219	1706.6	8.53	Repaired reasons of Earth fault	CLMT
400 kV insulator broken	2.4	1300	3120	156	Insulator string replaced	LLMT
220 kV insulator string blasted	3.2	180	576	28.8	Insulator string replaced	CLMT
400 kV, tripped on B-N fault	1.5	200	300	15	Removed fault	CLMT
220 kV, Single phase fault	2.1	200	420	21	Removed Earth fault	CLMT
220 kV tripped due to faulty cable spurious	2.4	156	374.4	18.72	Replace faulty cable	CLMT
220 kV, B phase Insulator flashover	3.2	120	384	19.2	Faulty insulator replaces	LLMT

3.1. Testing the fault classifier neural network

For performance analysis of trained neural network set of data is created separately as a third step of testing process. Performed simulation for different types of faults for 10 various test cases. Subsequent of test, set has been providing to neural network to get results. For the available input data plotted the linear regression as given in Figures 4 and 5. Figure 4 shows the validation result for 10 given epochs input data. Figure 5 shows the validation result for data output and object vs function which relates to the target output for given input data. Neural network may discriminate between ten (10) probable types of line faults with best accuracy. For the present case study correlation coefficient was found out to be 0.99645.

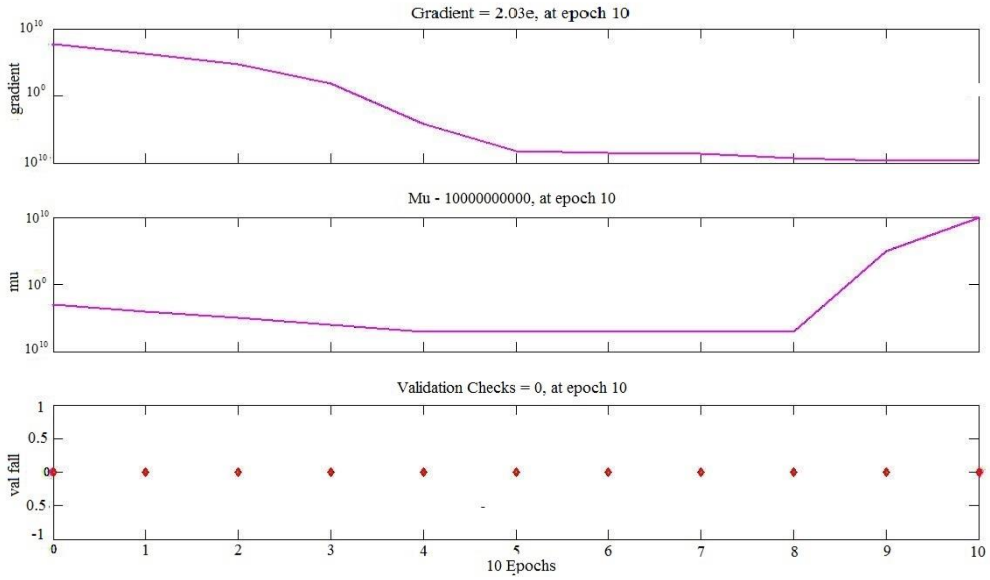


Figure 4. Validation result for 10 Epochs input data

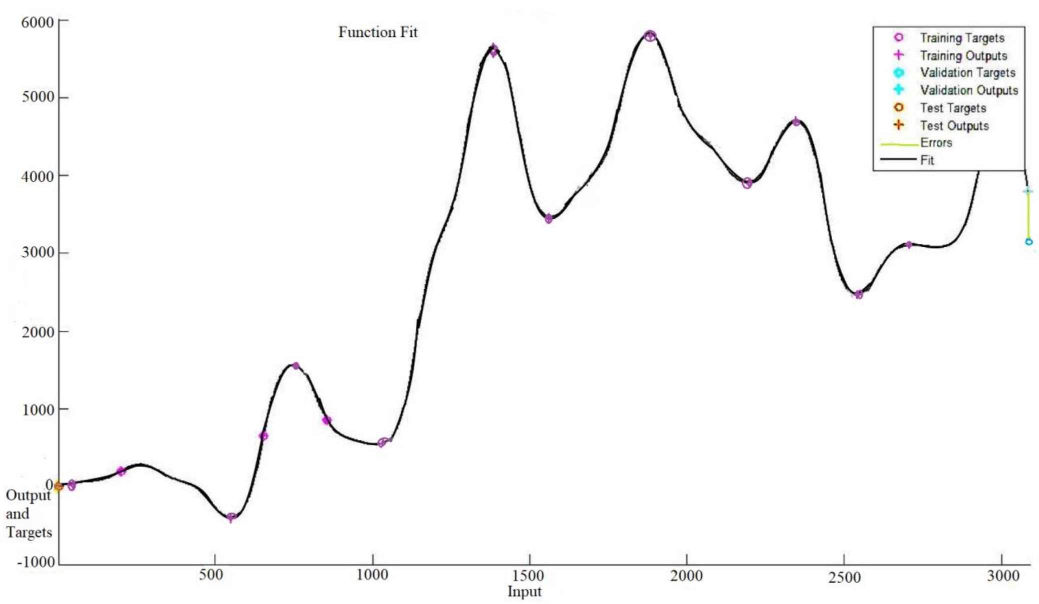


Figure 5. Data output and object vs function fix

Figure 6 shows training validations reports for 10 Epochs and Figure 7 shows best validation performance and delivers neural network summery as a screenshot of simulated training display using the Simulink toolbox of artificial neural network. This shows an acceptable correlation among the outputs and targets. Ideal regression fit indicated by dotted line and actual fit indicates by a solid line of green color for the neural network as shown in Figure 7. It is observed that both lines track each other precisely which marks as upright performance of neural network. This recommended to use recent advancements for different maintenance techniques which improve the power system performance [20], [21], [25], [26].

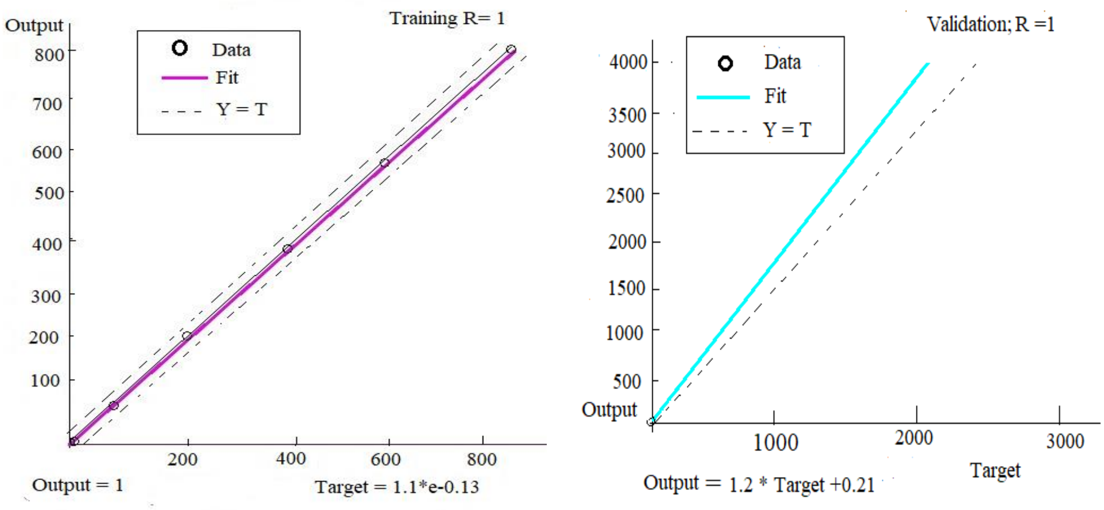


Figure 6. Training validation report for 10 Epochs'

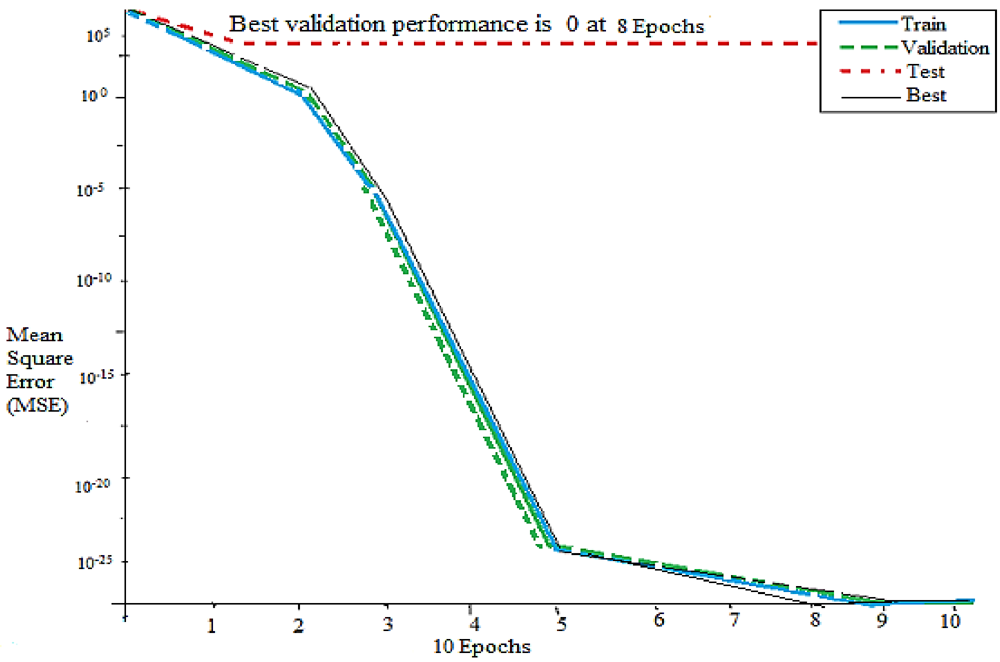


Figure 7. Best validation performance

4. RESULTS AND DISCUSSION

A case study for a line having total available hours in a year are 8760. Reliability analyses obtained through comparing calculations and measurements provides following results shown in Table 2 for CLMT and LLMT. Reliability analyses calculated following parameter to compare maintenance are downtime, repair time, average failure rate, available time, repair rate, mean time between failure and mean time to repair. Financial assessment of various technologies tells that in spite of penalties for de-energizing, revenue loss due to outages may be the main factor for development for line maintenance of transmission networks under live condition [6], [27], [28].

4.1. Improved reliability index parameter

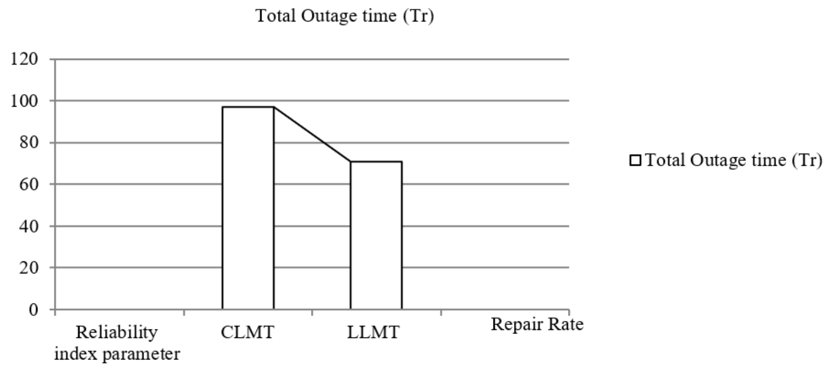
Table 2 shows calculation for various maintenance techniques applied and calculated reliability index parameter using given model. Table also shows percentage (%) improvement in parameter from the given calculation. It is observed that using LLMT various reliability index parameters are improved.

4.2. The reduction in total outage time and average failure rate

Table 2 shows initial maintenance is done with CLMT, the outage time was 125 Hr, after applying LLMT for some of the possible faults the outage time reduced to 87 Hrs. Figure 8 shows reduction in total outage time (Tr) from 97 to 71 Hr. This gives percentage improvement in parameter as 28 Hrs. Figure 9 shows reduction in total failure rate after applying maintenance on total 65 no of faults. The average failure rate with CLMT for given line was 845 and by using LLMT it was 117. Percentage (%) improvement in average failure rate was 13.86%. The economic analysis of live line maintenance (LLMT) with data of CLMT shows live line maintenance was more economical and opens new opportunity for improvement [26]–[28].

Table 2. Reliability index parameter and improvement in parameter using maintenance study model

Reliability index parameter for maintenance study	During complete outage-CLMT	LLMT and predictive maintenance work	Percentage (%) improvement in parameter
Total outage time downtime in Hr for (Tr)	97	71	28
Total outage time in Hr during repair (Tm)	125	87	30.4
Maintenance applied on total no of Faults (Ft)	65	65 (24)	36.92
Average failure (ft1)=Ft/Tm	0.52	0.27	44.23
Available time in a year Hrs-Tm	8635	8673	0.44
Mean time between failure (MTBF)=Tm/Ft	132.86	133.43	0.42
Repair rate r=Tm/Total Hrs in a year	0.01426	0.00993	30.93
Average failure rate λ=Ft/1-Ft.r	845	117	13.86
average failure rate per year λ/365	2.31	0.32	86.12
mean time to repair (mttr)=tm/ft	1.92	1.334	30.52
Repair rate (μ)=1/MTTR	0.518	0.75	44.78



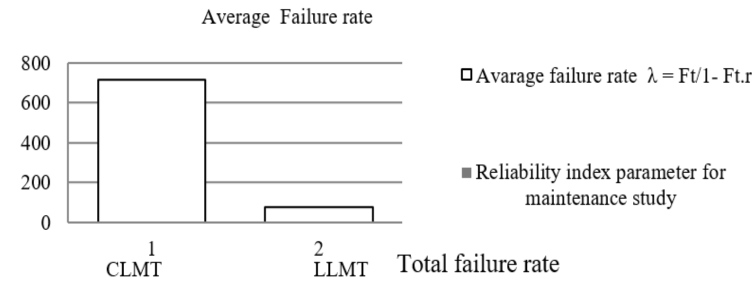


Figure 9. Reduction in total failure rate

4.3. The improvement in mean time to repair and repair rate

The table shows for a given transmission line, there were total 65 no of faults, out of 65 no. of faults LLMT maintenance was successfully applied on 24 no of faults. Thus, LLMT reduces no of faults up to 36.92%. For given transmission line MTBF for CLMT was 132.86 and MTTR 1.92 after applying LLMT. MTBF using LLMT improves to 133.43 and MTTR 1.334 for which mean time to repair improves by 30.52% compared to CLMT. Repair rate (μ) for CLMT was 0.518 and for repair rate (μ) for LLMT changes to 0.75. Thus, repair rate (μ) improved in above case as 44.72% using LLMT, thus improves the revenue for organization during available period.

5. CONCLUSION

The work reported takes in to account the state enumerate model for fault-finding. Markov method with a semi-forced outage systems diagram used for LLMT. The reliability analysis of the model is carried out for different kinds of faults considering the actual real time fault data. The performed statistical analysis evaluates the system outage time and power loss for the designated faults. The paper also reports the step-by-step procedure for fault identification with ANN model.

The practical implementation of LLMT validates the analysis results of maintenance using LLMT techniques and ANN as shown in Table 2. The two maintenance methods can be implemented to remove or minimized fault condition. By practical study in 35% fault cases LLMT can be applied, out of all types of faults. Application of LLMT in above model is limited to single phase pre fault situation and transmission line load adjustment. Using LLMT results shows downtime reduces to 30.4%, reduces average failure rate and improves availability thus increases revenue. It saves failure of related equipment and helps to maintain working condition of other equipment's, if tested and monitored. Thus, from above study LLMT under pre-fault conditions are recommended for managing continuity of supply. Coefficient of correlation in this case given by ANN to be 0.99645 for different 10 types of faults. Future scope of proposed work includes design and development of new model, method and its result validation considering other parameters for LLMT application.

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REFERENCES

[1] P. P. Mawle, G. A. Dhomane, and S. P. Dharmadhikari, "Transmission line maintenance management using early fault detection technique," in *2020 IEEE First International Conference on Smart Technologies for Power, Energy and Control (STPEC)*, Sep. 2020, pp. 1–6, doi: 10.1109/STPEC49749.2020.9297798.

[2] Y. Zhao, T. Li, X. Zhang, and C. Zhang, "Artificial intelligence-based fault detection and diagnosis methods for building energy systems: Advantages, challenges and the future," *Renewable and Sustainable Energy Reviews*, vol. 109, pp. 85–101, Jul. 2019, doi: 10.1016/j.rser.2019.04.021.

[3] M. I. Zaki, R. A. El Sehiemy, G. M. Amer, and F. M. Abo El Enin, "Sensitive/stable complementary fault identification scheme for overhead transmission lines," *IET Generation, Transmission and Distribution*, vol. 13, no. 15, pp. 3252–3263, Aug. 2019, doi: 10.1049/iet-gtd.2018.5016.

[4] Y. Q. Chen, O. Fink, and G. Sansavini, "Combined fault location and classification for power transmission lines fault diagnosis with integrated feature extraction," *IEEE Transactions on Industrial Electronics*, vol. 65, no. 1, pp. 561–569, Jan. 2018, doi: 10.1109/TIE.2017.2721922.

[5] J. Chitpong, C. Suwanasri, and T. Suwanasri, "Evaluation criteria for condition and importance assessment of high voltage transmission line," in *2016 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, Jun. 2016, pp. 1–6, doi: 10.1109/ECTICon.2016.7561237.

[6] P. Xu, Y. Zhang, Z. -Y. Liu, and H. -S. Chen, "Analysis on the fault of 2012 South China Grid above 220kV AC system and improvement methods," in *2014 China International Conference on Electricity Distribution (CICED)*, Sep. 2014, pp. 265–267, doi: 10.1109/CICED.2014.6991709.

[7] A. Ozdemir and E. D. Kuldasli, "RCM application for Turkish national power transmission system," in *2010 IEEE 11th International Conference on Probabilistic Methods Applied to Power Systems*, Jun. 2010, pp. 143–147, doi: 10.1109/PMAPS.2010.5528989.

[8] O. E. Obi, "An extended ann-based high speed accurate transmission line fault location for double phase toearth fault on non-direct-ground," *International Journal of Engineering Science Technologies*, vol. 1, no. 1, pp. 31–47, Aug. 2019, doi: 10.29121/IJOEST.v1.i1.2017.04.

[9] S. Shunmugam, "Live maintenance in high voltage substations: Malaysia's experience," in *2014 11th International Conference on Live Maintenance (ICOLIM)*, May 2014, pp. 1–4, doi: 10.1109/ICOLIM.2014.6934331.

[10] J. MacKinnon, S. Warnick, and J. McDaniel, "PLC based enterprise energy management solutions," in *2011 IEEE-IAS/PCA 53rd Cement Industry Technical Conference*, May 2011, pp. 1–7, doi: 10.1109/CITCON.2011.5934568.

[11] D. Zhang, W. Li, and X. Xiong, "Overhead line preventive maintenance strategy based on condition monitoring and system reliability assessment," *IEEE Transactions on Power Systems*, vol. 29, no. 4, pp. 1839–1846, Jul. 2014, doi: 10.1109/TPWRS.2013.2295379.

[12] M. N. Oltean, I. Sevastre, D. L. Brabete, and I. Rodean, "Live rehabilitation of 400 kV OHL Mintia-Sibiu," in *2014 11th International Conference on Live Maintenance (ICOLIM)*, May 2014, pp. 1–6, doi: 10.1109/ICOLIM.2014.6934348.

[13] W. Li, "Operation reliability of power systems." John Wiley & Sons, Inc., Oct. 2012, doi: 10.1002/047134608x.w8187.

[14] W. Li, Ed., "Outage models of system components," in *Risk Assessment of Power Systems*, Hoboken, NJ, USA: John Wiley and Sons, Inc., 2014, pp. 15–43, doi: 10.1002/9781118849972.ch2.

[15] P. P. Mawle, G. A. Dhomane, and P. G. Burade, "EHVAC transmission lines maintenance techniques in Indian perspective-A review," in *2016 International Conference on Global Trends in Signal Processing, Information Computing and Communication (ICGTSPICC)*, Dec. 2016, pp. 493–500, doi: 10.1109/ICGTSPICC.2016.7955351.

[16] K. Chaengakson, D. Rerkpreedapong, and K. Hongesombut, "Reliability improvement opportunity for 115-kV overhead transmission lines using RCM method," in *2019 IEEE PES GTD Grand International Conference and Exposition Asia (GTD Asia)*, Mar. 2019, pp. 808–812, doi: 10.1109/GTDAsia.2019.8716025.

[17] D. Glover and M. J. Sharma, "Transmission line parameter," *Power System Analysis and Design*, pp. 159–209, 2012
[18] W. Li, "Data in probabilistic transmission planning," in *Probabilistic Transmission System Planning*, John Wiley and Sons, Inc., 2011, pp. 149–179, doi: 10.1002/9780470932117.ch7.
[19] A. Arnaiz, E. Konde, and J. Alarcón, "Continuous improvement on information and on-line maintenance technologies for increased cost-effectiveness," *Procedia CIRP*, vol. 11, pp. 193–198, 2013, doi: 10.1016/j.procir.2013.07.038.
[20] J. H. Heo, M. K. Kim, and J. K. Lyu, "Implementation of reliability-centered maintenance for transmission components using particle swarm optimization," *International Journal of Electrical Power and Energy Systems*, vol. 55, pp. 238–245, Feb. 2014, doi: 10.1016/j.ijepes.2013.09.005.
[21] L. Xu and M.-Y. Chow, "A classification approach for power distribution systems fault cause identification," *IEEE Transactions on Power Systems*, vol. 21, no. 1, pp. 53–60, Feb. 2006, doi: 10.1109/TPWRS.2005.861981.
[22] A. Jain and B. Moses, "Soft computing based fault detection & classification for transmission lines," in *2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, Mar. 2016, pp. 4061–4064, doi: 10.1109/ICEEOT.2016.7755477.
[23] J. I. Aneke, O. A. Ezechukwu, and R. U. Ebune, "Artificial intelligence based fault detection and classification in transmission lines," *Iconic Research And Engineering Journals*, vol. 2, no. 4, pp. 38–46, 2018
[24] X. Zhao and J. Zhou, "Probabilistic transient stability assessment based on distributed DSA computation tool," in *2010 IEEE 11th International Conference on Probabilistic Methods Applied to Power Systems*, Jun. 2010, pp. 685–690, doi: 10.1109/PMAPS.2010.5528324.
[25] A. J. Snyders, J. Ferguson, J. H. R. Enslin, and P. P. Reichmeider, "Avoiding costly plant shutdowns by employing specialized live technologies and safe practices," in *IEEE PES General Meeting*, Jul. 2010, pp. 1–6, doi: 10.1109/PES.2010.5589453.
[26] P. P. Mawle, G. A. Dhomane, and P. G. Burade, "Smart grids to improve power scenario of transmission and distribution sectors in India," *IJRITT*, vol. 4, no. 5, pp. 5–20, 2016
[27] S. Alexandru, M. Oltean, T. Fagarasan, I. Sevastre, and L. Brabete, "Live replacement of 400kv busbar insulators in Brasov substation," in *2011 IEEE PES 12th International Conference on Transmission and Distribution Construction, Operation and Live-Line Maintenance (ESMO)*, May 2011, pp. 1–7, doi: 10.1109/TDCLLM.2011.6041631.
[28] Z. Bertalan, J. Kiss, and Z. A. Tamus, "Technical economic feasibility study on live line maintenance on Hungarian transmission network," in *2014 11th International Conference on Live Maintenance (ICOLIM)*, May 2014, pp. 1–4, doi: 10.1109/ICOLIM.2014.6934349.

BIOGRAPHIES OF AUTHORS

Prashant P. Mawle received M. E. degree from Amravati University, Maharashtra, India, in 2005. He Published more than 6 paper in National, International conferences and journals. His areas of interest are electrical power system, transmission system and distribution system. He can be contacted at ppmawle1@gmail.com.

Gunwant A. Dhomane received Ph.D. degree from Visvesvaraya National Institute of Technology (VNIT), Nagpur University, India, in 2010. Presently he is working as Professor and Head in Electrical Engineering Dept and Dean (R and D) of Govt. College of Engineering Amravati, India. He Published more than 52 papers in national, International conference and Journals. His research interest includes power electronics drives and control, high power factor converters, renewable source and smart grid integration. He can be contacted at email: gadhomane@gmail.com.

Prakash G. Burade received Ph.D. From RTMNU, Nagpur University in 2012. Presently working as professor and Head of Electrical Department at Sandip University, Nashik, India. He has published 35 research papers in reputed international journal and more than 15 papers in international conference. He has issue 4 patents in his recognition. His interested areas are custom power device, power electronics, power system optimization and FACTS devices. He can be contacted at: prakash.burade@gmail.com.