# Redundancy allocation problem_Agung2015

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# An Investigation on Imperialist Competitive Algorithm for Solving Reliability-Redundancy Allocation Problems

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*Abstract* - **Reliability-redundancy allocation problems (RRAPs) are optimization models that try to find the optimal number of redundant components and their reliability levels simultaneously. Many studies have been developed to solve RRAPs in recent years. There are some specific RRAP models for various system structures to maximize system reliability subject to cost, volume and weight constraints. Different meta-heuristic algorithms have been used in order to reach the best objective function value. In this study, an investigation is done on imperialist competitive algorithm (ICA) to maximize models for series and bridge systems. ICA is used by adjusting different values to algorithm's parameters. This investigation recognizes which combination is the most suitable for solving the RRAPs by ICA. Each combination has been run for 35 times. Therefore, the combinations are compared by descriptive statistics' measures and analysis of variance (ANOVA). Furthermore, the best obtained solution is compared with the previous studies.**

*Keywords* - **Reliability-redundancy allocation problem; Imperialist competitive algorithm; Comparison; Analysis of variance**

## I. INTRODUCTION

Finding an optimal solution for system reliability optimization models plays an important role in reliability area. Reliability-redundancy allocation problem (RRAP) is a reliability optimization model that aims to find the optimal system design and improvement decisions. Many studies have been developed to solve RRAPs by meta-heuristic approaches in recent years [1-5]. In this paper, the capability of imperialist competitive algorithm (ICA) which is a recent meta-heuristic method has been investigated to solve RRAPs for series and bridges systems. Different values are adjusted to different parameters in ICA. This investigation can show the impact of each parameter on ICA's efficiency to find optimal solutions in system reliability optimization models. Also, it can provide an opportunity for researchers to develop an improved meta-heuristic approach based on ICA.

## II. RELIABILITY-REDUNDANCY OPTIMIZATION MODEL

The aim of reliability engineering is to improve the reliability of the systems [6]. In reliability-redundancy optimization models, the objective function is to maximize system reliability subject to constraints. The variables are the number of components and their reliability in each subsystem as Eqs. (1) and (2).

$$Maximize\ R_s = f(r,x) \quad (1)$$

$$subject\ to\ g(r,x) \le b \quad (2)$$

$$r_i \epsilon \mathbb{R}, 0 \le r_i \le 1, x_i \epsilon \mathbb{Z}^+, 1 \le i \le n$$

where $R_s$ is the reliability of the system, $f(\cdot)$ is the objective function for the system reliability, $g(\cdot)$is the set of constraint functions which is associated with system weight, volume and cost, *b* is the resource limitation, n is the number of subsystems, $r = (r_1, r_2, \ldots, r_n)$ is the vector of the component reliabilities so that $r_i$ is the reliability of the components in *i*th subsystem, and $x = (x_1, x_2, \ldots, x_n)$ is the vector of the redundancy allocation so that $x_i$ is the number of components in *i*th subsystem. The problem belongs to the category of constrained nonlinear mixed integer optimization problems.

Series structure is one of the simplest types of structure that have been used in many electrical and mechanical systems. If a component fails, then a series system fails. The bridge system is a complex structure in which an interconnection element transmits the surplus capacity to the other part [7]. The configuration of the series and bridge systems are presented in figures 1 and 2 respectively. The mathematical formulations of the reliability-redundancy optimization model for series and bridge systems which were presented in [8]are described in Eqs. (3)-(7). Equation (3) shows the objective function of the series system, and equation (4) denotes the objective function of the bridge system. Both optimization models are subject to the same constraints.

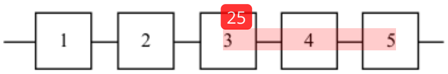

Figure 1.Series system

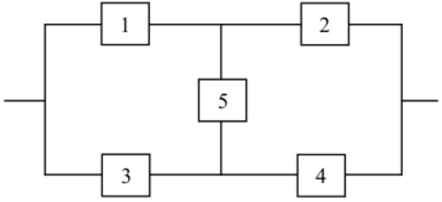

Figure 2. Bridge system

$$Maximize\ f(r,n) = \prod_{i=1}^{n} R_i(x_i) \quad (3)$$

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$$Maximize\ f(r,n) = R_1 \cdot R_2 + R_3 \cdot R_4 + R_1 \cdot R_4 \cdot R_5 + R_2 \cdot R_3 \cdot R_5 - R_1 \cdot R_2 \cdot R_3 \cdot R_4 - R_1 \cdot R_2 \cdot R_3 \cdot R_5 - R_1 \cdot R_2 \cdot R_4 \cdot R_5 - R_1 \cdot R_3 \cdot R_4 \cdot R_5 - R_2 \cdot R_3 \cdot R_4 \cdot R_5 + 2R_1 \cdot R_2 \cdot R_3 \cdot R_4 \cdot R_5 \tag{4}$$

Subject to

$$g_1(r,x) = \sum_{i=1}^{n} w_i \cdot v_i^2 \cdot x_i^2 \leq V \tag{5}$$

$$g_2(r,x) = \sum_{i=1}^{n} \alpha_i \cdot \left(\frac{-1000}{\ln r_i}\right)^{\beta_i} \cdot \left[x_i + e^{\left(x_i/4\right)}\right] \leq C \tag{6}$$

$$g_3(r,x) = \sum_{i=1}^{n} w_i \cdot \left[x_i \cdot e^{\left(x_i/4\right)}\right] \leq W \tag{7}$$

where V is the upper limit of the sum of the subsystems' volume, C is the upper limit of the system cost, W is the upper limit of the system weight, $w_i$ and $v_i$ are the weight and volume of each component in *i*th subsystem, $\alpha_i$ and $\beta_i$ are physical features of *i*th subsystem components. The constraint (4) is the combination of weight, redundancy allocation and volume. The constraint (5) and (6) are cost and weight constraints respectively. As can be seen, there are five subsystems in the systems,so $n = 5$. The input parameters of the series system are shown in Table I.

Table I
DATA USED IN THE SERIES AND BRIDGE SYSTEMS

| Subsystem | $10^5 \cdot \alpha_i$ | $\beta_i$ | $w_i \cdot v_i^2$ | $w_i$ | $V$ | $C$ | $W$ |
|---|---|---|---|---|---|---|---|
| 1 | 2.330 | 1.5 | 1 | 7 | 110 | 175 | 200 |
| 2 | 1.450 | 1.5 | 2 | 8 | | | |
| 3 | 0.541 | 1.5 | 3 | 8 | | | |
| 4 | 8.050 | 1.5 | 4 | 6 | | | |
| 5 | 1.950 | 1.5 | 2 | 9 | | | |

## III. IMPERIALIST COMPETITIVE ALGORITHM

In this section, a brief introduction is brought for ICA which was firstly introduced by Atashpaz-Gargari in 2007 [9]. ICA is an evolutionary algorithm inspired by socio-political evolution of humans which is known as colonial competitive algorithm (CCA) as well. An initial population is formed in which each solution is a country. These countries are divided into two groups of colonies and imperialists. Imperialist countries try to dominate more countries and assimilate the colonies to their selves. This process continues until one imperialist country exists. Therefore, the last imperialist is considered as the optimal solution.

The colonies are moved toward the imperialist by a vector with size called assimilation coefficient (AC) and angle called assimilation angle coefficient (AAC). These two parameters follow the uniform distribution. This assimilation process provides an opportunity to generate new solutions for the problem. This movement of the colonies makes possible that a colony becomes more powerful than the imperialist. In this situation, the colony and the imperialist swap their positions. This process can be called as a revolution. In addition, imperialists compete with each other to add more colonies to their territory. The imperialists are compared with a total cost value which consists of the imperialist cost and summation of colonies' cost which is multiplied by a constant value of zeta. Both revolution and imperialist competition assure the convergence for ICA.

Some studies have been done to improve ICA. Azad et al [10] combined ICA with opposition-based learning (OBL) to accelerate the convergence speed. Afonso et al [2] applied attraction and repulsion concepts on AC to find better optimal results for RRAPs. Also, ICA is compared with genetic algorithm (GA) to solve a complex system reliability optimization model in [11].

## IV. INVESTIGATION

In this section, the impact of two parameters, AC and zeta, on finding the optimal solutions for reliability-redundancy optimization problem of both series and bridge systems are investigated. Three different values as 1, 2 and 3 have been considered for AC. In addition, three different values as 0.001, 0.02 and 0.3 are allocated to zeta. Other parameters have been remained constant. The number of countries in the population is 90, and initial empires are 15. Also, the algorithm continues to reach 1000th iteration. There are 9 combinations based on the variable parameters. The model is programmed by Matlab software, and each combination was run for 35 times to make a statistical comparison.

### *A. Series system*

#### *1) Descriptive analysis*

Based on the runs' results, the statistical measures like mean, minimum (the worst), maximum (the best), and standard deviation (STD) for series system are obtained. The results are shown in Table II.

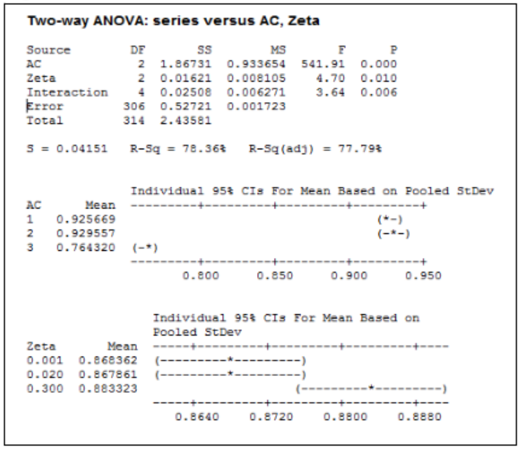
Table II
DESCRIPTIVEANALYSIS RESULTS FOR SERIES SYSTEM

| Parameters | | Max | Min | Mean | STD |
|---|---|---|---|---|---|
| AC | Zeta | | | | |
| 1 | 0.001 | 0.930580549 | 0.889863054 | 0.922740173 | 0.0071791 |
| | 0.02 | 0.931473431 | 0.911936371 | 0.926226956 | 0.0041429 |
| | 0.3 | 0.931568058 | 0.921602789 | 0.928039526 | 0.0031664 |
| 2 | 0.001 | 0.931672394 | 0.924601663 | 0.929491950 | 0.0022013 |
| | 0.02 | 0.931675503 | 0.924200465 | 0.929303545 | 0.0019991 |
| | 0.3 | 0.931650992 | 0.923910195 | 0.929875931 | 0.0020673 |
| 3 | 0.001 | 0.869844812 | 0.583923937 | 0.752855273 | 0.0721624 |
| | 0.02 | 0.857199052 | 0.576649928 | 0.748053114 | 0.0753107 |
| | 0.3 | 0.879625169 | 0.641611507 | 0.792052590 | 0.0673431 |

As can be seen, the optimal solutions are found by AC=2 have higher mean, maximum, and minimum values. In addition, they have the lowest STD values. It reveals that this adjustment stably searches and explores the optimal solutions with a small variation. On the contrary, the obtained solutions by AC=3 have the worst situation. Furthermore, the optimal solutions have the highest mean values and the lower STD values when zeta is equal to 0.3. These different results are emerged because different adjustments can change the searching path of ICA to reach the optimal solutions.

### 2) *Analysis of variance*

To assess whether the impact of parameters is significant, the analysis of variance (ANOVA) has been done on the results. The software Minitab 16 is used. Figure 3 shows the results of ANOVA.



```
Two-way ANOVA: series versus AC, Zeta

Source        DF       SS        MS       F      P
AC             2  1.86731  0.933654  541.91  0.000
Zeta           2  0.01621  0.008105    4.70  0.010
Interaction    4  0.02508  0.006271    3.64  0.006
Error        306  0.52721  0.001723
Total        314  2.43581

S = 0.04151   R-Sq = 78.36%   R-Sq(adj) = 77.79%


              Individual 95% CIs For Mean Based on Pooled StDev
AC       Mean  ---------+---------+---------+---------+
1    0.925669                                   (*-)
2    0.929557                                   (-*-)
3    0.764320  (-*)
               ---------+---------+---------+---------+
                    0.800     0.850     0.900     0.950


                 Individual 95% CIs For Mean Based on
                 Pooled StDev
Zeta        Mean  -----+---------+---------+---------+----
0.001   0.868362  (---------*---------)
0.020   0.867861  (---------*---------)
0.300   0.883323                    (---------*---------)
                  -----+---------+---------+---------+----
                    0.8640    0.8720    0.8800    0.8880
```

Figure 3. ANOVA results for series system

As can be seen, the p-value for three tests of AC, zeta and interaction are 0.000, 0.01, and 0.006 respectively which are less than acceptable alpha level of 0.05. As a result, for the objective function values of the seriessystem, there is significant evidence for anAC-zeta interaction impact for confidence level of 95 percent. Also, there are significant evidences for AC and zeta main effects on finding optimal solutions by ICA.

### 3) *Comparison*

The adjusted ICA has been used for solving the series RRAP model over 3000 iterations with country number and initial empire number 150 and 15 respectively.The results are compared with the existing methods. Table III shows the best solution is obtained by different methods.

As can be seen, the adjusted meta-heuristic method is able to find better solutions for series system in comparison with the previous studies.

## B. *Bridge system*

### 1) *Descriptive analysis*

The descriptive statistical measures for bridge system have been identified. The results are shown in Table IV.

Table IV

DESCRIPTIVEANALYSIS RESULTS FOR BRIDGE SYSTEM

| Parameters | | Max | Min | Mean | STD |
|---|---|---|---|---|---|
| AC | Zeta | | | | |
| 1 | 0.001 | 0.999889139 | 0.999581613 | 0.999828327 | 6.6815e-05 |
| | 0.02 | 0.999887161 | 0.999561219 | 0.999783568 | 9.8864e-05 |
| | 0.3 | 0.999885706 | 0.999488464 | 0.999769634 | 9.1465e-05 |
| 2 | 0.001 | 0.999883363 | 0.999361194 | 0.999702266 | 0.1584e-05 |
| | 0.02 | 0.999589395 | 0.999360574 | 0.999576113 | 5.3833e-05 |
| | 0.3 | 0.999839084 | 0.997191187 | 0.999411122 | 0.6939e-05 |
| 3 | 0.001 | 0.999589252 | 0.997189938 | 0.999504014 | 0.4064e-05 |
| | 0.02 | 0.999589124 | 0.999338123 | 0.999546870 | 8.1607e-05 |
| | 0.3 | 0.999588896 | 0.999323382 | 0.999544833 | 8.5045e-05 |

As can be seen, the higher values of mean, maximum, and minimum are found when AC is equal to 1. However, the lowest STD values belong to AC=2. In addition, the optimal solutions are quite better when 0.001 is allocated to zeta.

### 2) *Analysis of variance*

Similar to the series system, ANOVA is performed on the optimal results of bridge system. The results of ANOVA are shown infigure 4. According to the p-value results, the impact of AC and zeta are significant for solving bridge RRAP models by ICA as well. As can be seen, different values have been found for AC and zeta when the problem is formed as a bridge system. In [9], the founder of ICA recommends a value of about 2 for AC. However, we found that an AC value of 1 can have better performance in some cases.

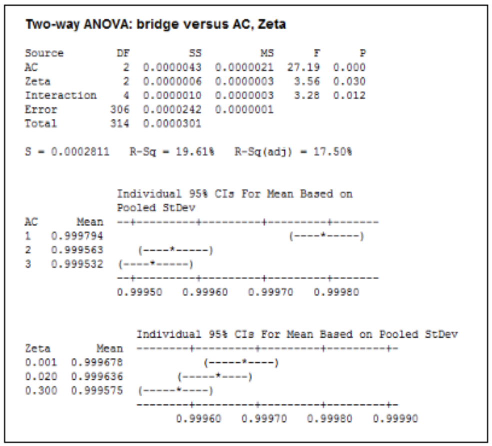
Table III

COMPARISON RESULTS FOR SERIES SYSTEM

| Parameters | Kuo et al. [12] | Xu et al. [13] | Hikita et al. [14] | Hsieh et al. [15] | Chen [8] | Wu et al. [16] | Afonso et al. [2] | The adjusted ICA |
|---|---|---|---|---|---|---|---|---|
| $f(r,n)$ | 0.92975 | 0.931677 | 0.931363 | 0.931578 | 0.931678 | 0.931680 | 0.931679 | 0.93168138 |
| $x_1$ | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| $x_2$ | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $x_3$ | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $x_4$ | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| $x_5$ | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| $r_1$ | 0.77960 | 0.77939 | 0.77714 | 0.77943 | 0.779266 | 0.780373 | 0.779874 | 0.779760 |
| $r_2$ | 0.80095 | 0.87183 | 0.86751 | 0.86948 | 0.872513 | 0.871783 | 0.872057 | 0.872088 |
| $r_3$ | 0.90227 | 0.90288 | 0.89669 | 0.90267 | 0.902634 | 0.902409 | 0.903426 | 0.902689 |
| $r_4$ | 0.71044 | 0.71139 | 0.71774 | 0.71404 | 0.710648 | 0.711474 | 0.710960 | 0.711405 |
| $r_5$ | 0.85947 | 0.78779 | 0.79389 | 0.78689 | 0.788406 | 0.787387 | 0.786902 | 0.787208 |

### 3) *Comparison*

The RRAP model for bridge system is solved by ICA via adjusting the obtained values. The adjusted ICA has been used over 5000 iterations with country number and initial empire number 150 and 15 respectively. The results are compared with some of the previous methods. Table V compares different methods in terms of the obtained solutions. It shows that the adjusted ICA can find the acceptable solution values.



**Two-way ANOVA: bridge versus AC, Zeta**

```
Source        DF         SS         MS      F      P
AC             2  0.0000043  0.0000021  27.19  0.000
Zeta           2  0.0000006  0.0000003   3.56  0.030
Interaction    4  0.0000010  0.0000003   3.28  0.012
Error        306  0.0000242  0.0000001
Total        314  0.0000301

S = 0.0002811   R-Sq = 19.61%   R-Sq(adj) = 17.50%


              Individual 95% CIs For Mean Based on
              Pooled StDev
AC      Mean  --+---------+---------+---------+-------
1   0.999794                           (----*-----)
2   0.999563     (----*-----)
3   0.999532  (----*-----)
              --+---------+---------+---------+-------
              0.99950   0.99960   0.99970   0.99980


                 Individual 95% CIs For Mean Based on Pooled StDev
Zeta      Mean  --------+---------+---------+---------+-
0.001  0.999678           (-----*----)
0.020  0.999636       (-----*----)
0.300  0.999575 (-----*----)
                --------+---------+---------+---------+-
                      0.99960   0.99970   0.99980   0.99990
```

Figure 4. ANOVA results for bridge system

Table V

COMPARISON RESULTS FOR BRIDGE SYSTEM

| Parameters | Hikita et al. [14] | Hsieh et al. [15] | Kim et al. [17] | The adjusted ICA |
|---|---|---|---|---|
| $f(r,n)$ | 0.999789 | 0.999879 | 0.9998876 | 0.99988817 |
| $x_1$ | 3 | 3 | 3 | 3 |
| $x_2$ | 3 | 3 | 3 | 3 |
| $x_3$ | 2 | 3 | 3 | 3 |
| $x_4$ | 3 | 3 | 3 | 3 |
| $x_5$ | 2 | 1 | 1 | 1 |
| $r_1$ | 0.814483 | 0.814090 | 0.807263 | 0.821868 |
| $r_2$ | 0.821383 | 0.864614 | 0.868116 | 0.875922 |
| $r_3$ | 0.896151 | 0.890291 | 0.872862 | 0.855427 |
| $r_4$ | 0.713091 | 0.701190 | 0.712667 | 0.696573 |
| $r_5$ | 0.814091 | 0.734731 | 0.751034 | 0.746230 |

## V. CONCLUSION

Different parameter values can affect ICA efficiency in solving RRAP optimization models. Therefore, the meta-heuristic approach should be tuned before application via finding optimum values. In this paper, it is proven that two parameter AC (assimilation coefficient) and zeta (constant coefficient of colonies' cost) have a significant impact on finding the optimal solutions for RRAPs. The investigation has been done on both series and bridge (complex) systems. For series systems, it is recommended to adjust AC and zeta values as 2 and 0.3 respectively. For bridge system, AC=1 and zeta=0.001 are the best values for ICA. As a result, an adjusted ICA (AICA) is proposed for solving RRAP optimization models in this study.

For further research, other parameters of ICA can be assessed to find the most suitable values. Also, this investigation can be done on different system structures such as series-parallel, and the over-speed protection system, and other reliability optimization models. Moreover, the adjusted ICA can be run for more generations to find the best optimal solution for RRAPs. The last but not the least;researchers can work on adjusted ICA to develop a new meta-heuristic approach which is an attractive research area.

## REFERENCES

[1] Abouei Ardakan, M. & Zeinal Hamadani, A. Reliability–redundancy allocation problem with cold-standby redundancy strategy. *Simulation Modelling Practice and Theory* 42 107-118, 2014.

[2] Afonso, L. D., Mariani, V. C. & Dos Santos Coelho, L. Modified imperialist competitive algorithm based on attraction and repulsion concepts for reliability-redundancy optimization. *Expert Systems with Applications* 40 (9), 3794-3802, 2013.

[3] Kanagaraj, G., Ponnambalam, S. G. & Jawahar, N. A hybrid cuckoo search and genetic algorithm for reliability-redundancy allocation problems. *Computers and Industrial Engineering* 66 (4), 1115-1124, 2013.

[4] Valian, E. & Valian, E. A cuckoo search algorithm by Lévy flights for solving reliability redundancy allocation problems. *Engineering Optimization* 45 (11), 1273-1286, 2013.

[5] Zou, D., Gao, L., Wu, J., Li, S. & Li, Y. A novel global harmony search algorithm for reliability problems. *Computers and Industrial Engineering* 58 (2), 307-316, 2010.

[6] Khorshidi, H. A., Gunawan, I. & Ibrahim, M. Y. An optimization model for multi-state weighted k-out-of-n system reliability value. *Industrial Electronics Society, IECON 2013 - 39th Annual Conference of the IEEE*, 4357-4361, 2013.

[7] Khorshidi, H. A., Gunawan, I. & Ibrahim, M. Y. Investigation on system reliability optimization based on classification of criteria.in *Proc.IEEE International Conference on Industrial Technology (ICIT)*, South Africa, 2013.

[8] Chen, T. C. IAs based approach for reliability redundancy allocation problems. *Applied Mathematics and Computation* 182 (2), 1556-1567, 2006.

[9] Atashpaz-Gargari, E. & Lucas, C. Imperialist competitive algorithm: An algorithm for optimization inspired by imperialistic competition. *IEEE Congress on Evolutionary Computation, CEC 2007*, 4661-4667, 2007.

[10] Azad, H. R. L., Boushehri, N. S. & Mollaverdi, N. Investigating the application of opposition concept to colonial competitive algorithm. *International Journal of Bio-Inspired Computation* 4 (5), 319-329, 2012.

[11] Khorshidi, H. A. & Nikfalazar, S. Comparing Two Meta-Heuristic Approaches for Solving Complex System Reliability Optimization. *Applied and Computational Mathematics* 4 (2-1), 1-6, 2015.

[12] Way, K., Hwang, C.-L. & Tillman, F. A. A Note on Heuristic Methods in Optimal System Reliability. *IEEE Transactions on Reliability* R-27 (5), 320-324, 1978.

[13] Xu, Z., Way, K. & Lin, H.-H. Optimization limits in improving system reliability. *IEEE Transactions on Reliability* 39 (1), 51-60, 1990.

[14] Hikita, M., Nakagawa, Y., Nakashima, K. & Narihisa, H. Reliability optimization of systems by a surrogate-constraints algorithm. *IEEE Transactions on Reliability* 41 (3), 473-480, 1992.

[15] Hsieh, Y.-C., Chen, T.-C. & Bricker, D. L. Genetic algorithms for reliability design problems. *Microelectronics Reliability* 38 (10), 1599-1605, 1998.

[16] Wu, P., Gao, L., Zou, D. & Li, S. An improved particle swarm optimization algorithm for reliability problems. *ISA Transactions* 50 (1), 71-81, 2011.

[17] Kim, H. G., Bae, C. O. & Park, D. J. Reliability-redundancy optimization using simulated annealing algorithms. *Journal of Quality in Maintenance Engineering* 12 (4), 354-363, 2006.

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