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Compute the Reliability and the Entropy of South Iraqi Super Grid

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ABSTRACT: The concepts of network reliability and entropy play a vital role in various real-world applications. This study presents a reliability assessment of the South Iraqi super grid by employing the minimal path technique. It also includes the generation of a probability density function and the calculation of entropy to better understand system performance. Furthermore, a custom algorithm was developed using MATLAB 2014 to perform the reliability evaluation of the super grid system in southern Iraq.

Key Words: Reliability , minimal path , entropy.

Contents

1. Introduction

Network reliability analysis receives attention for the design, effectiveness, and protection of the many real-world systems in (2019) Abeer presented a new method for estimating the reliability of a system have one terminal [1]. The Iraqi electrical national grid consists of 400kv super grid and 123 kv ultra-high voltage electrical power transmission networks, and it consists of 33kv and 11 kv system distribution networks. In ([15], Mohammed evaluates the reliability of 400kv by minimal path method Ėntropy, a concept originally rooted in thermodynamics and information theory. Has gained wide acceptance in studying complex network structures . In the context of networks, entropy measures the amount of uncertainty or disorder in the structure or behavior of the network. It provides insights into how information is distributed across the network and helps quantify the complexity, regularity, or randomness of the connections between nodes. [7] Iraqi electrical power system is divided in to six subsystems R1 is Iraqi North Zone reliability index, R2 is Dyala- Anbar Zone reliability index, R3 is Baghdad North Zone reliability index, R4 is Iraqi Middle Zone reliability index and R6 is Iraqi South Zone reliability index. Therefore, this paper focuses on evaluating the reliability of the Iraqi super grid system electrical national will calculate by reduction method and then construct a novel probability density function is proposed in this study as in the following paragraphs in this paper will dells with south Iraqi super grid that consist of

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ten city khor-Alzuber, Hartha, Nasiriyah, south Reign, Kadisiyah, Babil, Middle Regin, Kut , Baghdad South and Mesayab . [2], [6] .

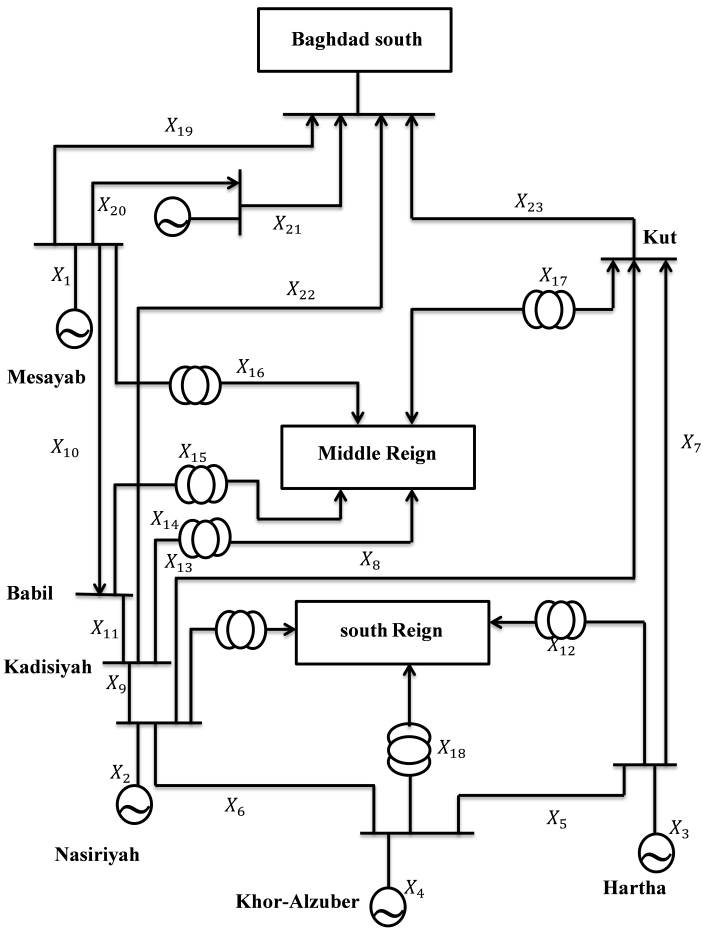

Figure 1: represents south Iraqi super gride ,this network was divided into six section, each section representing a specifid station for wich reliability was calculated.

2. Basic Concept

Reliability of series system

The reliability of a series system is the probability that component succeeds and and all of the other components in the system succeed so the reliability given by

$$R_{sys} = p_r(x_1 x_2 \cdots x_n) = \Pi_{i=1}^{n} pr(x_i) = \Pi_{i=1}^{n} R_i \tag{2.1}$$

Reliability of the parallel system

If at least one of components must succeed for the system to succeed, then the system called parallel system so to find the reliability

$$R_{sys} = 1 - \Pi_{i=1}^{n}(1 - R_i) \tag{2.2}$$

Series – parallel system

It is a system that consists of different subsystems connected in series. Each subsystem consists of components connected in parallel as . The reliability of the system is

$$R_s = 1 - \Pi_{k=1}^{m}(1 - \Pi_{i=1}^{n_k}(1 - R_i)) \tag{2.3}$$

Shanoon Entropy
Shannon's entropy quantifies the amount of information in a variable, thus providing the foundation for a theory around the notion of information. Shannon entropy is defined by:

$$H = -E(\log?(p(x))). \tag{2.4}$$

Here, $p(x)$ represents the likelihood that the system occupies cell x within its phase space reliability [3,11,12,16,10,7].

3. MINIMALPATH METHOD

This approach finds a minimum path by building a connected matrix. The nodes in a two-terminal network are flawless, while the edges are prone to failure. A connection matrix must be built to develop a minimal path using this method. A basic graph's $n \times n$ adjacency matrix and identity matrix will be combined as follows:

$$CM = \begin{matrix} \\ 1 \\ 2 \\ \vdots \\ n \end{matrix} \begin{bmatrix} & \textit{To node} & & \\ 1 & 2 & \cdots & n \\ 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 0 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{2n} & \cdots & 1 \end{bmatrix} + \begin{matrix} \\ 1 \\ 2 \\ \vdots \\ n \end{matrix} \begin{bmatrix} & & & \\ 1 & 2 & \cdots & n \\ 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix}$$

the result after combining is combination

$$CM = \begin{matrix} \\ 1 \\ 2 \\ \vdots \\ n \end{matrix} \begin{bmatrix} & \textit{To node} & & \\ 1 & 2 & \cdots & n \\ 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{2n} & \cdots & 1 \end{bmatrix}$$

The term $a_{ij} = (i, j)$ denotes the presence of a connection between nodes i and j, where the set $\{1, 2, \cdots, n\}$ includes all nodes in the network. Nodes that do not serve as either the source or the destination are progressively removed from the connection matrix (CM) until only the source and sink nodes are left, as referenced in [8,4,5,14,13]. When a link exists between nodes i and j, the matrix entry is given by $a_{ij} = x_{ij}$; otherwise, $a_{ij} = 0$. An update rule is then applied to revise the connection matrix based on the remaining nodes after each removal :

$$a_{ij}^{1} = a_{ij} + a_{ij}a_{lj}$$

If node 1 is removed, where $i \neq j, i \neq l, j \neq l, 1 \leq i < n, 1 < j \leq n$ for $i = 1, 2, \ldots, n$.

4. EVALUATION THE RELIABILITY OF IRAQI SUPER GRID.

In this pargraph of the research, Assessing the reliability of the Iraqi electrical super grid will be calculated. Calculation the reliability of figure 1 is NP-Hard, so in this paper depended on the minimal path method to estimate the reliability of south Iraqi super grid. After display minimal path method gets all minimal path of figure 1 as follows:

$$p1 = x1x19, p2 = x2x13, p3 = x4x18, p4 = x3x12,$$
$$p5 = x2x9x22, p6 = x2x8x23, p7 = x3x5x18, p8 = x3x7x23,$$
$$p9 = x4x6x13, p10 = x3x5x6x13, p11 = x4x6x9x22, p12 = x4x6x8x23$$

So by applied equation 5 gets the reliability of south Iraqi super grid as follow

$$R(t) = R1R9 + R2R13 + R4R18 + R3R12 + R2R9R22 + R2R8R23 + R3R5R18 + R3R7R23 + R4R6R13 + R3R5R6R13 + R4R6R13 + R3R5R6R13 + R4R6R9R22 + R4R6R8R23 \tag{4.1}$$

5. THE PR.OBABILITY DENSITY FUNCTION OF IRAQI SUPER GRID

From the information of Iraq's electricity supply and demand, 2010- 2017.

And according to Kolmogorov-Simonov test, electricity consumption is increasing and approaching

Table 1: Iraqi's electricity supply and demand (in kWh)

Year	Domestic	Commercial	Governmental	Agricultural	Industrial
2010	12,622,187	1,537,225	7,027,800	689,264	5,567,285
2011	11,072,685	1,446,026	6,079,683	636,299	6,321,307
2012	13,885,716	1,910,332	8,916,237	1,166,778	7,484,381
2013	17,571,511	2,717,505	12,279,354	1,509,536	9,042,037
2014	17,070,854	2,791,115	12,915,706	929,274	8,724,183
2015	20,276,941	3,087,472	11,549,188	671,955	6,449,184
2016	17,952,433	1,936,788	12,093,705	645,284	4,123,331
2017	24,993,174	2,483,965	7,553,790	709,790	5,029,902

an exponential distribution
By the probability theory the reliability system is defined

$$R(x) = p(X > x) = 1 - P(X \leq x) = 1 - F(X) \tag{5.1}$$

Since the distribution of Iraqi super grid is exponential then the cumulative density probability (cdf) is $F(x) = 1 - e^{(-\lambda x)}$ where λ greater than zero By substitute equation (5.1) in equation (4.1) gets

$$R(x) = 4e^{-2\lambda x} + 5e^{-3\lambda x} + 3e^{-4\lambda x}. \tag{5.2}$$

In probability theory there is a relationship between the reliability and a pdf

$$f(x) = -dR(x). \tag{5.3}$$

So the probability density function of south Iraqi super grid is

$$f(x) = 8e^{(-2\lambda x)} + 15e^{(-3\lambda x)} + 12e^{(-4\lambda x)}. \tag{5.4}$$

6. EVALUATION THE ENTROPY OF SOUTH IRAQI SUPER GRID

In this section will compute the entropy of south Iraqi super grid , by substitute equation (6.1) in equation (2.4) gets

$$H = E(\log?(p(x)) = \int_0^{\infty} \log(8e^{(-2\lambda x)} + 15e^{(-3\lambda x)} + 12e^{(-4\lambda x)})e^{(-\lambda x)}dx \tag{6.1}$$

Ater integrate it get $H = 1.7675$

7. EVALUATION THE ENTROPY OF EDGE OF SOTH IRAQI SUPER GRID

Edges entropy is a measure of diversity of edge in a network. The degree (i) represents the number of direct connections (edges) associated with the i^{th} node in the network . To calculate the structure entropy of Complex, the degree of Complex network is defined as follows:

$$P_i = \frac{(Degree(i))}{(\sum_{(} i = 1)^n Degree(i))} \tag{7.1}$$

Where the P_i It represents the current degree of the i^{th} node, which will be used in the calculation of structural entropy [17]. it is def by

$$P_i = \frac{(Degree(i))}{(\sum_{(i=1)}^{n} Degree(i))}$$

such that N represents the total of the node set in the network
K is the Boltzmann universal. So the edges entropy is $E_{edg} = -k\sum_{(i=1)}^{n}(P_i \log?(P_i))$ So in south Iraqi super grid total nods 14 and total degree 20 as shown in the following table

Node	Degree
Baghdad south	1
Middle Reign	3
South Reign	5
Others (11 remaining nodes).	

Each has 1 After display equation 12 and equation 13 gets

$$Edeg = (0.5 + 0.4105 + 120.2161) \simeq 0.5 + 0.4105 + 2.5932 = 3.50$$

bits

8. EVALUATION THE ENTROPY OF BETWEENNES OF SOUTH IRAQI SUPER GRID

Entropy of betweenness is a measures of the diversity of the paths passing through a node in a network . The details of definition of the betweenness are shown as follows :

$$V(i) = \sum_{(s\neq i\neq t)} \frac{(\sigma_{st}(i))}{\sigma_{st}}$$

where the $V(i)$ indicates the betweenness centrality of the i^{th} node.
The σ_{st} Represents the total number of shortest paths from node s to node t.
The $\sigma_{st}(i)$ Indicates how many of the shortest paths in the network traverse the i^{th} node.
Betweenness structure entropy for a complex network can be expressed as follows :

$$E_{bet} = -\sum_{i=1}^{n} p_i' \log p_i' \tag{8.1}$$

Where the $P_i^{'}$ is defined as follows :

$$P_i^{'} = \frac{V(i)}{\sum_{i=1}^{n} V(i)}$$

the $V(i)$ represents the betweenness which is defined above. in south Iraqi super grid have 12 minimal path , in Baghdad $P_i^{'} = 1/12$, in Middle Reign $P_i^{'} = 3/12$, south Reign $P_i^{'} = 5/12$, others nods $P_i^{'} = 1/12$, so after display equation 14 , gets

$$E_{bet} = 2.19\text{bits}$$

Table 2 show the comparison between kinds of entropy of south Iraqi super grid

Table 2: Comparison between kinds of entropy of South Iraqi super grid

Entropy Type	**Value (bits)**	**Meaning**
Edge Entropy	3.50	Edges are fairly evenly distributed among nodes good connectivity.
Betweenness Entropy	2.19	Flow of information is moderately centralized key nodes dominate paths.
Shannon Entropy	1.59	Node degrees are uneven some nodes are hubs while others are under connected.

9. Conculution

The reliability and entropy of the South Iraqi Super Grid, particularly the 400 kV transmission network, are critical factors influencing the stability and efficiency of Iraq's power system. Recent studies have employed various methodologies to assess and enhance these aspects. In this paper compute the reliability and many kind of entropy , Shannon entropy, edge entropy and between entropy and get that the Shannon entropy equally 1.59, edges entropy equaled 3.50 and betweens entropy equaled 2.19. and that's mean recently, Edges are fairly evenly distributed among nodes good connectivity. Flow of information is moderately centralized key nodes dominate paths. Node degrees are uneven some nodes are hubs while others are under connected. .

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