Planned Reliability Improvement Calculation of Iraqi Super Grid Applying Fuzzy Logic Method

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Abstract:

Reliability is an essential measure and important component of all power system planning and operation procedures. It is one of the key design factors when designing complex, critical and expensive systems. This paper presents a fuzzy logic approach for reliability improvement planning purposes.

Evaluating the reliability of the complex and large planned Iraqi super grid ;as Al- Khairat generating station with its tie set is intended to be compact to that grid; and determination of the given reliability improvement project are the major goals of the paper.

Results show that the Iraqi super grid reliability is improved by 9.64%.

In the proposed technique, fuzzy set theory is used to include imprecise indices of different components in normal reliability calculations applying a Matlab program and that method can be used as a powerful tool for planning to improve systems reliablity.

Keywords: Fuzzy Logic, Reliability planning, HL II Reliability assessment.

Nomenclature

HL: hierarchical level
MTTF: mean time to failure
MTTR: mean time to repair

Introduction

Reliability of a power system is defined as the ability of power system to supply consumers' demand continuously with acceptable quality.

The determination of the actual reliability of the system may not be as valuable as the determination of where to spend money to obtain the most improvement in reliability [1] i.e; the network must meet that balance reliability, cost, and quality.

Power systems can be divided into the three functional zones of: generation, transmission, and distribution. These functional zones can be combined to create three Hierarchical Levels (HL) which provide a practical framework for power system reliability evaluation.

HL I reliability assessment in which the transmission lines are assumed to be fully reliable and without transmission limits. Thus, only the models of load and generators are considered. This level usually termed as “generating capacity adequacy evaluation”, is mainly concerned with assessing the amount of generating capacity that must be installed in order to satisfy the perceived system load and to perform necessary corrective or preventive maintenance with an acceptable level of risk.

HL II analysis, termed as “Composite system reliability evaluation” or “bulk power system reliability evaluation”, is concerned with the composite problem of assessing the generation and transmission facilities in regard to their ability to supply adequate, dependable and suitable electrical energy at the bulk power load points.

HL III analysis includes all three functional zones. The objective of an HL III is to obtain suitable adequacy indices at actual consumers load points. In addition to the basic three hierarchical levels, assessment can be performed separately on any system subset such as sub transmission, substation, switching stations and generating stations [2].

Many research and development studies were performed to develop methods and criteria for reliability evaluation and quality assessment of system of generation, transmission and distribution [2].

Studying the power system reliability is usually conducted with the aid of the Markov model on the assumption that state transition rates are constant [3].

In this research Markov states are defined according to the possible probabilistic states governing the life cycle of system components, while fuzzy concepts are used to model uncertainty and vague related to future failure and repair indices and consequently expected future reliability of the grid is calculated. In fact, the failure probability of a system or a part of it changes as time passes or as some circumstances such as system environment changes. Because effective factors on reliability continuously change over time, the best approach to evaluate the reliability is its real time assessment. To reach this goal, the time interval for evaluating the reliability should be shortened to as much extent as possible. Nevertheless, such an uncertain situation can be modeled using fuzzy sets theory. Fuzzy logic provides powerful tools to consider these uncertainties and their modeling.

Fuzzy sets allow the user to interpret in a holistic way how uncertainties are reflected in the results [4]. The proposed method is a technique to evaluate composite systems reliability using fuzzy logic and it is examined on Iraqi super grid.

Iraqi Super Grid [5]

The 400 kV grid largely consists of single circuit construction overhead lines built in the early seventies. Longer 400 kV lines are normally equipped with 50MVAR terminal shunt reactors at each end of the line.

It contains 26 transmission lines, 17 transformers that transfer voltage (400-132) KV, and the 11 generating stations are connected to that grid.

Iraqi electrical power system is divided from the control point of view into three operational subsystems: North, Middle, and South region which are operated and controlled as a unified interconnected system.

North region network contains Mosul Dam, Baiji PS, Baiji GPS, and Kirkuk GPS stations, while middle region contains Haditha Dam, Quds GPS, Musayab PS, and Musayab GPS, and south region contains Hartha PS, Nassirya PS, and Khur Al-Zubair GPS.

Figures (1, 2, and 3) illustrate the three regions network.

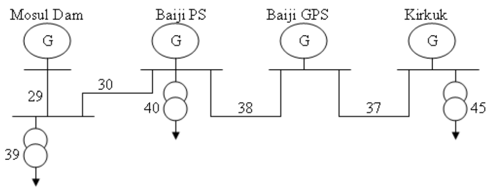


Fig.1. North region network.

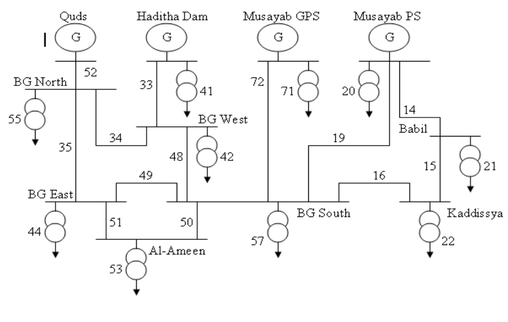


Fig.2. Middle region network.

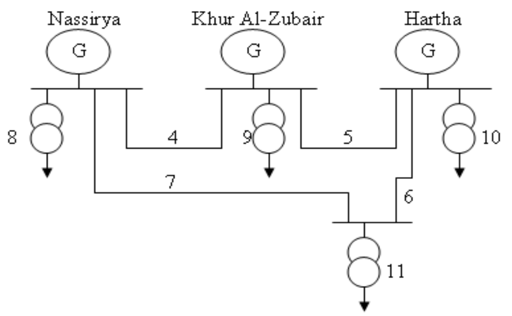


Fig.3. South region network.

Table (1) shows the data of power stations of Iraqi 400kV super grid for 2010.

Table1. Power station's average production per hour [5].

Power Station Name	Standard Power Supply(MW)	Output in 2010(MW)
Mosul Dam	4*187.5	206.87
Baiji P S	6*220	349.2
Baiji GP S	4*159	265.42
Kirkuk G P S	1*65 & 1*260	201.54
Haditha Dam	6*110	130
Quds G P S	6*123 & 4*43	459.7
Musayab P S	4*300	351.25
Musayab G PS	9*50	21.1
Hartha P S	4*200	303.75
Nassirya P S	4*210	422.42
Khur Al-Zubair GPS	4*63 & 2*123	269.42

The generation planning studies indicate the need for new generation; naturally transmission system development must accompany the generation development; beyond the committed plant in ministry of electricity's plan, also recommends that future generation should be based on gas as fuel.
Studies and information received from the ministry of electricity indicated that, by 2015 and beyond, Iraq would have enough gas to fuel its future generation.

Mean time to failure/ repair

Probability methods are widely used for reliability planning by representing equipment failure and repair processes by stochastic models, considering forced and planned outage rates; it is inadequate to represent failure and repair rates, or in other words, MTTF and MTTR by expected (crisp) values for the whole planning horizon. In order to represent uncertainty in expert system, the analysis begins from a fundamental model of uncertainty based on fuzzy mathematics. Such an analysis leads to a rule-based expert system development to effectively extract information from available data for obtaining coherent conclusion.
The knowledge of the experts is represented by some rules so as to incorporate the overall uncertainty [6].

Fuzzy logic

Fuzzy logic and fuzzy sets are used to heuristically quantify the meaning of linguistic variables, linguistic values, and linguistic rules that are specified by the expert.
This model is based on the fuzzy set theory to deal with some form of non random uncertainties: associated with vagueness of new parts of Al- Khairat generating unit, transmission lines and (400/132) KV transformer that are to be compact to the grid in order to improve its performance, also associated with imprecision and lack of future information regarding failure and repair rates of different old parts of the grid as some system circumstances changes.

Such failure and repair rates depend not only on components themselves, but also on other systematic factors that include company efficiency and operation policy. Consequently, some uncertainties are associated with component indices and this uncertainty is of nonprobabilistic type.
The knowledge of the experts is represented by some rules so as to incorporate the overall uncertainty. As in any rule-based system, the rules are chained together by what is called the inference engine. The fuzzy definition of mean time to failure may be thought of as built over underlying exponential

fuzzy distribution of failure rates. It is assumed that uncertainties related to MTTF can be incorporated through evaluation of experts who are well acquainted with the characteristics of the generation system and operation policy. For example, the minimum and maximum values of MTTF can be obtained based on expert evaluation.

Thus MTTF can be represented by an "interval of confidence" rather than a crisp value.

The standard fuzzy membership numbers is called triangular fuzzy numbers, to represent the uncertain parameter such as MTTF are based on intuition [6]. Such memberships are derived from the capacity of humans through their innate intelligence and understanding involving contextual and semantic knowledge as well as linguistic truth-values about an issue.

Temperature

The maximum ambient temperature of the power plants is particularly important for the analysis as this will affect the performance of the plant. As the failure rate increases with increasing temperature, the worst case will occur in the summer months, when the temperature is at its highest range.

In order to determine the average summer temperature, daily temperature data was analysed for the three regions, north, middle and south, between the years 2005 to 2009. The absolute maximum temperature for each year is averaged and was 48°C over the three locations, and occurred in the period July to August. Hence it is sufficient to say that the average maximum ambient temperature during the summer months in Iraq is 44.4°C. This value was rounded up to 45°C and used in the analysis [5].

After selecting membership functions, proper rules should be defined.

Definition of rules is often based on human logic and experts' skills. For example, it is known that if the temperature was high, the capacity of transmission lines would decrease, thus MTTF decreases.

The linguistic variable temperature is represented by a term set, given by:

t1: cold, t2: moderate, and t3: hot

Length

The length of the transmission lines in kilometers is another variable included in the fuzzy model. Because the risk of interruption is assumed to be increased by an increased length of the line, this variable is again represented by a linguistic fuzzy set; as the location of Al-Khairat power station is uncertain till now. The linguistic variable length is represented by a term set, given by: Very Short, Short, Medium, Long, and Very Long. The length of the line section can be much longer in some systems. However, this is a representative domain for the length of the sections

Al khairat power plant

Al Khairat Gas station will be compact to the middle region network and its connection to that network is illustrated in Fig.4.

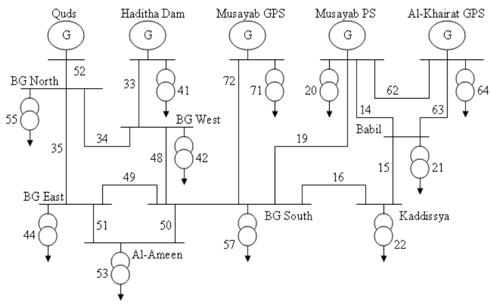


Fig.4. Planned middle region network

he plant is located to the south-east of Kerbala with a capacity of 3*400 KV and designed for a plant lifetime of 30 years; the generator belongs to the GE power series of three-phase generator.

It is assumed to operate mainly in base load and its reliability depends upon the

maintenance level and impact on the life cycle cost.
Repairs and preventive maintenance actions is a part of the overall scheduled maintenance programme that includes periodic overhauls also [5].

Case study

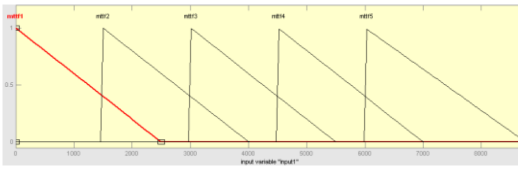
AL-Khairat Tie Set's Indices Uncertinties Calculation

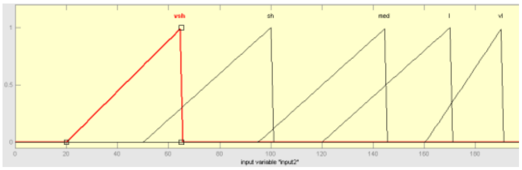
A linguistic declaration such as:
"MTTF of the generating station will surely not below 480 hours or above 1488 hours per year; considering the worst conditions of temperature and the lack of fuel; and the best estimate is 984 hours" will be translated into a triangular fuzzy number instead of a crisp value of 984 hours for a generating unit.
"MTTR boundaries of uncertainty for fuzzy variables are obtained considering the effect of maintenance scheduling and will surely not below 48 hours or above 144 hours per year, and the best estimate is 72 hours" is also translated into a triangular fuzzy number instead of a crisp value of 72 hours.
Inference engine obeys the rules of Mamdani Inference engine whose structure has been defined as below:

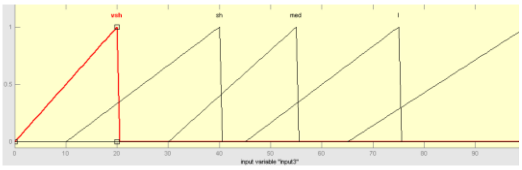
Rules governing the value of Failure rate are:

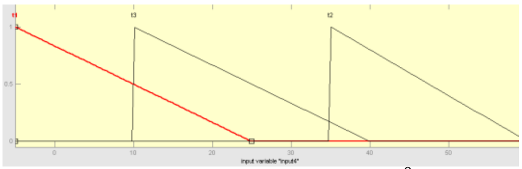
1.If (input 1 is mttf1) or (input 2 is vsh) or (input 3 is vsh) or (input 4 is t1) then (output is fr5).
2.If (input 1 is mttf2) or (input 2 is sh) or (input 3 is sh) or (input 4 is t1) then (output is fr4).
3.If (input 1 is mttf3) or (input 2 is med) or (input 3 is med) or (input 4 is t2) then (output is fr3).
4.If (input 1 is mttf4) or (input 2 is l) or (input 3 is l) or (input 4 is t3) then (output is fr2).
5.If (input 1 is mttf5) or (input 2 is vl) or (input 3 is vl) or (input 4 is t3) then (output is fr1).

Memberships of the MTTF, length of first tie line, length of second tie line, and temperature that is forming the rules governing failure rate value are shown in Fig.5.


(a) Input-1- for MTTF in one year


(b) Input-2- for Length of first tie


(c) Input-3- for Length of second tie


(d) Input-4- for Temperature ^{0}C

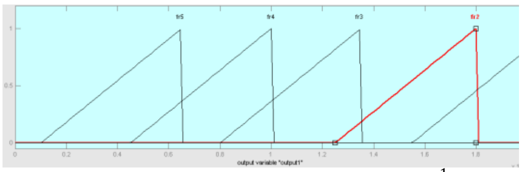

(e) Output for Failure rate in hour^{-1}

Fig.5. (a) - (e) Membership functions of inputs and output to calculate Al-Khairat tie set failure rate.

Note:

The explaination of the abbriviations used in construcring the rules are:

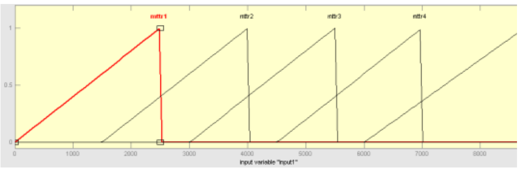
l: long vl: very long

sh: short vsh: very short
t1: cold t2: moderate
t3: hot fr: failure rate
rr: repair rate

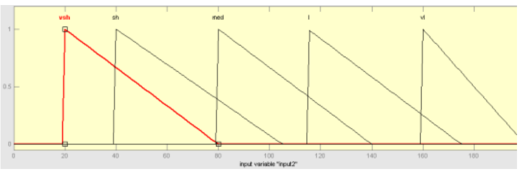
Rules governing the value of repair rate are:

6. If (input 1 is mttr1) or (input 2 is vl) or (input 3 is vl) or (input 4 is t1) then (output is rr1).
7. If (input 1 is mttr2) or (input 2 is l) or (input 3 is l) or (input 4 is t1) then (output is rr2).
8. If (input 1 is mttr3) or (input 2 is med) or (input 3 is med) or (input 4 is t2) then (output is rr3).
9. If (input 1 is mttr4) or (input 2 is sh) or (input 3 is shl) or (input 4 is t3) then (output is rr4).
10. If (input 1 is mttr5) or (input 2 is vsh) or (input 3 is vsh) or (input 4 is t3) then (output is rr5).

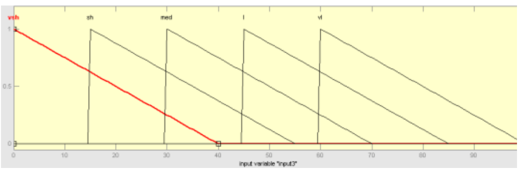
Memberships of the MTTR, length of first tie line, length of second tie line, and temperature that is forming the rules governing repair rate value are shown in Fig.6.



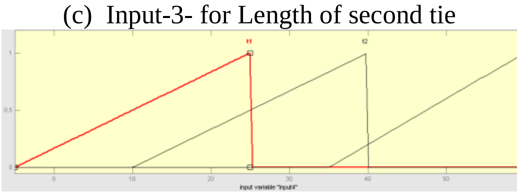
(a) Input-1- for MTTR in one year



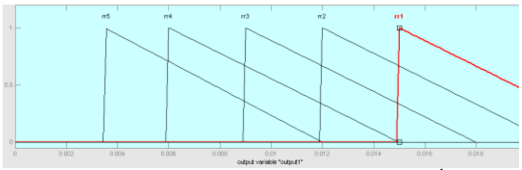
(b) Input-2- for Length of first tie



(c) Input-3- for Length of second tie



(d) Input-4- for Temperature ^{0}C



(e) Output for Repair rate in hour^{-1}

Fig.6. (a) - (e) Membership functions of inputs and output to calculate Al-Khairat tie set repair rate.

Results of Al-Khairat Indices

When applying rules, the resultant failure rate is $1.02*10^{-3}$ as shown in Fig.7.

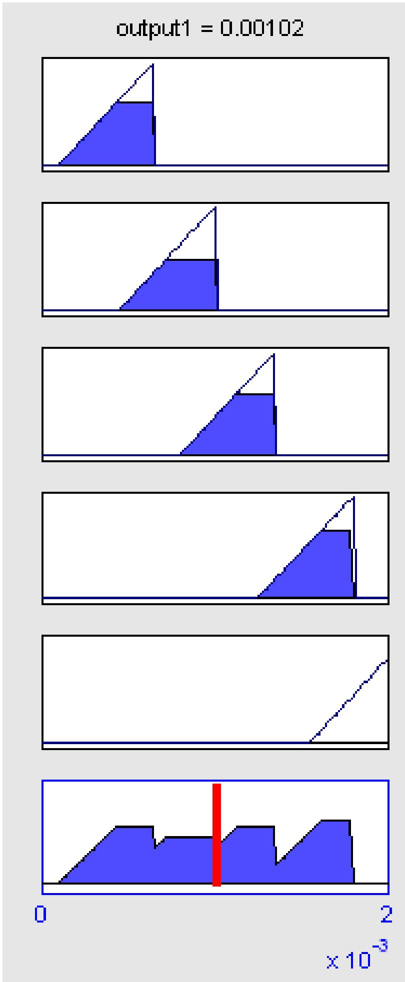


Fig.7. Failure rate result

Rules governing the value of repair rate is applied and repair rate is found to be $1.26*10^{-2}$ as shown in Fig.8.

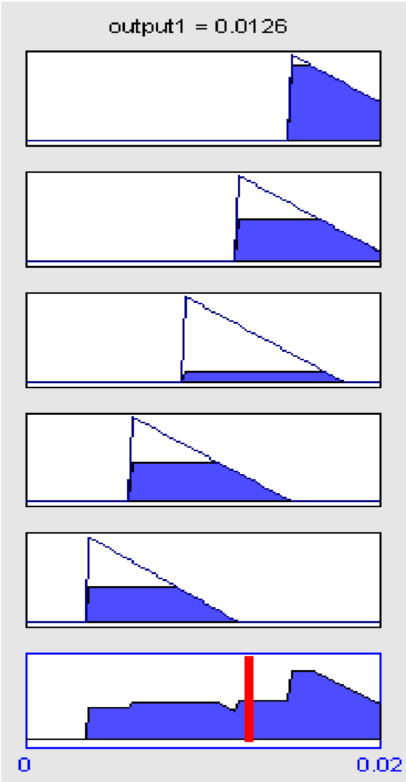


Fig.8. Repair rate result

Five generating stations including Al-Khairat station are connected to the middle region transmition network forming five tie sets as shown in Fig.4.
Indices of other generating stations tie sets are found, utilizing experts' knowledge base, as shown in table 2.
Each tie set has 2 states: good and failure and there will be 2^n states of the system, where n is the number of tie sets i.e. 32 is the possible system states.

Table2. Middle RegionTie sets' failure &repair rates

Tie set name	Failure rate	Repair rate
Musayab PS	1.65e-4	3.35e-4
Musayab GPS	1.28e-4	3.07e-3
Haditha Dam	1.12e-4	1.56e-4
Quds	1.03e-4	3.29e-4
Al-Khairat	1.02e-3	1.26e-2

Failure and repair rates of each generating tie set that is given in table 2., is used to model Markov states, and the resultant reliability of middle region is:

R_m=45.65 %

Iraqi super grid; consists of the three regions in parallel connection; reliability is:

R_T= 85.06 %

It is evident that parallel connection between the three regions is raising the total reliability of Iraqi super grid.

Conclusion

To demonstrate the reliability improvement of the complex and large planned Iraqi super grid; as Al- Khairat generating station with its tie set is compact to that grid; from reliability calculations it is found that:
Calculated reliability of middle region before improvement is:

R_m= 10.61 %

Iraqi super grid reliability before improvement is:

R_T= 75.42 %

When comparing old results with these of planned system it is obvious that Al-Khairat tie set is raising the reliability of Iraqi super grid by (9.64 %) which means that the station is improving the performance of the grid with a good factor.
This study is useful to calculate reliability planned improvement for any bulk power system.

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حساب تحسين الوثوقية لشبكة الضغط الفائق العراقية المخطط لها باستعمال الطريقة المنطقية الضبابية

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الخلاصة:
الوثوقية هي مقياس أساسي وعنصر مهم لتطوير كل منظومات القدرة وخطوات عملها. هي أحد مقاييس التصميم للمنظومات المعقّدة,الغير مستقرة,والمكلفة. البحث هذا يعرض وسيلة المنطق الضبابي لأغراض التخطيط لتطوير الوثوقية.
إن تقويم الوثوقية لشبكة الضغط الفائق العراقية المعقّدة المخطط تطويرها بدمج محطة توليد الخيرات ومجموعة وصلها الى الشبكة, وتحديد مشروع تحّسين الوثوقية هي الأهداف الرئيسية لهذا البحث.
النتائج توضح أن نسبة تحسين الوثوقية لشبكة الضغط الفائق العراقية هو 9,64٪.
إن التقنية المعروضة, إستخدمت نظرية المجموعة الضبابية لتضمين المعاملات الغامضة لمختلف العناصر في الحسابات المعتادة للوثوقية بتطبيق برنامج ماتلاب ويمكن إستعمال هذه الطريقة كوسيلة متينة لتحسين وثوقية المنظومات المزمع تطويرها.