*N***-1 Contingency Parallel Analysis of Main**
 Transformers in Distribution Networks

Qiubo Zou, Fengzhang Luo, Tianyu Zhang
 Abstract—^{*N*-1} security criterion is an important criterion for

the development and plann *N*-1 Contingency Parallel Analysi

Transformers in Distribution Ne

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the development and planning of distribution net ICAL Method of

Vsis of Main

Networks

I. INTRODUCTION

eration and dispatching of distribution

verification and evaluation are needed

the most commonly used verification icle has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication.

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gency Parallel Analysis of Main

ners in Distribution Networks

Qiubo Zou, Fen

existing *^N***-1 contingency analysis methods of distribution network are most and the unit of components, and the faults of each**
 **are most on the development and planning of distribution networks. The

are mostly based on the unit of components, and the faults of each

are mostly based component are analyzed and verified one by one. The calculation component are analyzed and verified one by one. The development are mostly based on the unit of components, and the faults of each are mostly based on the u Process of these methods is complicated, and the positioning effect** and by extended incidence matrix. Firstly, the main transformer incidence matrix and the vertex position of the vertex of the existing N -1 contingenc Qiubo Zou, Fengzhang Luo, Tianyu Zhang
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the development and planning of distribution networks. The

existing N-1 contingency analysis methods of distribution networks, ence

are mostly based** *Abstract***—N-1 security criterion is an important criterion for I. If the development and planning of distribution networks. The existing N-1 contingency analysis methods of distribution network and the planning, operati Abstract—N-1 security criterion is an important criterion for**
 the development and planning of distribution networks. The
 **existing N-1 contingency analysis methods of distribution network

are mostly based on the un** *Abstract*—N-1 security criterion is an important criterion for

the development and planning of distribution networks. The

existing N-1 contingency analysis methods of distribution network

are mostly based on the unit o **capacity** constraint of an important criterion of the planning constraints are ensuly based on the unit of components, and the faults of each are mostly based on the unit of components, and the faults of each are mostly b Existing *N*-1 contingency analysis methods of distribution networks. The planning, operation are mostly based on the unit of components, and the faults of each and the partworks, security verification are mostly based on **EXECUTE THE CONFERGY SECTS ANDELLED ANDELLED ANDELLED TRANSFER CONDITION (THE CONFERGINGLY AND THE CONFERGING INTERFERGING INTERFERGING INTERFERGING INTERFERGING INTERFERGING INTERFERGING INTERFERGING INTERFERGING INTERFE** are mosty based on the tim to component are analyzed and verified one by one. The calculation [1][2]. At present, the process of these methods is complicated, and the positioning effect method is distribution of the weak l External are analyzed and vertiled one by our the catenarion in the process of these methods is complicated, and the positioning effect in this contingency and the vertifies whether the insufficient. For this reason, this process or these methods is completed, and the positioning enter the most complete include is distinuited contingency parallel analysis of main transformer based on N-1 system can be guaranteed contingency parallel analysi of the was mass hece in the transferring in the word incomparison of the proposes and the logical analysis of main transformer based on interaction incidence matrix. Firstly, the main transformer incidence matrix contingen **EXECUTE:** For this reason, this paper proposes a method of 17-1
 transformers and the load transformer incidence matrix component fault occurs in

is established, and the load transfer process is classified into three
 comingency paramet anasos of main transformer based on the control of the process of and the load transformer incidence matrix contingency analysis of c
types according to different transformer ways, and the contact means **An example is given to verify the correctness and effectiveness of the strain and the base in the base in the content in the content and the method. The method is a strained method. The matrices are established respectively. Secondly, considering the network operation, and capacity contr result of all main transformers in the distribution retwork in the content of main transformers and the V-1 contingency analysis result is all capacity considering the interaction, and it is all capacity constraint of mai Example is example to expectively. Secondly, considering the intervolvement corresponding capacity matrices are established. The maximum great significance to the pixely transfer capability (MTC) of the distribution netwo links can be intuited in the intuitively.** The emperation of the attention paid to the plantified act indicators, we determine that is actualled by contact matrices of each main transformer fault is calculated by contact corresponding capacity matrices are establistical corresponding capacity that is calculated by contact matrices
of each main transformer fault is calculated by contact matrices
and capacity matrices, and the *N*-1 continge Fransier capability (WIC) of the ustribution nead
of each main transformer fault is calculated by
and capacity matrices, and the *N*-1 contingency
obtained by comparing MTC with the le
transferring. Meanwhile, the transfer **Index Terms—Distribution network;** *N*-1 contingency analysis; From the *N*-1 security mathematic experime the transfer margin of main fault can be transferred uniformers and tie-lines after transfer margin of main fault betware by comparing FIFTC with the base that costs that the state transformers and tie-lines after transferring can be obtained in the process of *N*-1 contingency analysis, so as to find weak links.
An example is given t

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Lel Analysis of Main

Tibution Networks

wo, Tianyu Zhang

I. INTRODUCTION

n the planning, operation and dispatching of distribution

networks, security verification and evaluation are needed

[[2]. At present, the most c CE Analysis of Main

Cibution Networks

wo, Tianyu Zhang

I. INTRODUCTION

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networks, security verification and evaluation are needed

[[2]. At present, the most co **EXECUTE ALCOVERT LATE CONTROVERT (2014)**

Luo, Tianyu Zhang

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I. INTRODUCTION

Intervorks, security verification and evaluation are needed

[1][2]. **EXECUTE IS A THE EXECUTE IS A THE MANUS CONTROVERT IN THE PLANUIT ON THE PLANUIT OF THE PLANUIT AND THE PLANUIT AND THE PLANUIT AND THE SURFER WHEN THE SURFER EXECUTE INCREMENT INCREMENT AND TANK THE CONTRACT TO A THE CONTRACT THE CONTRACT THE CONTRACT THE CONTRACT CONTRACT THE CONTRACT THE CONTRACT THE CONTRACT THE CONTRACT THE CONTRACT THE CONTRACT CONTRACT CONTRACT CONTRACT** Luo, Tianyu Zhang

I. INTRODUCTION

I. INTRODUCTION

Inetworks, security verification and evaluation are needed

[1][2]. At present, the most commonly used verification

method is distribution network $N-1$ contingency an Luo, Tianyu Zhang

I. INTRODUCTION

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Inetworks, security verification and evaluation are needed

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Inetworks, security verification and evaluation are needed

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method is distribution network $N-1$ contingency an **I.** INTRODUCTION
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In the planning, operation and dispatching of distribution

[1][2]. At present, the most commonly used verification

method is distribution network N -1 contingency analysis,

which verifies whether the I. INTRODUCTION

I. INTRODUCTION

Inetworks, security verification and evaluation are needed

[1][2]. At present, the most commonly used verification

method is distribution network N -1 contingency analysis,

which veri 1. INTRODUCTION
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 I. The planning, operation and dispatching of distribution
 $[1][2]$. At present, the most commonly used verification

method is distribution network $N-1$ contingen network. networks, security verification and evaluation are needed [[2]. At present, the most commonly used verification thod is distribution network *N*-1 contingency analysis, eich verifies whether the continuous power supply of [1][2]. At present, the most commonly used verification
method is distribution network N -1 contingency analysis,
which verifies whether the continuous power supply of the
system can be guaranteed by switching operation method is distribution network *N*-1 contingency analysis,
which verifies whether the continuous power supply of the
system can be guaranteed by switching operation after a single
component fault occurs in the distribution which verifies whether the continuous power supply of the system can be guaranteed by switching operation after a single component fault occurs in the distribution network. N -1 contingency analysis of distribution netwo Inetworks, security verification and evaluation are needed

**Checking each component is avoided, and the computational

efficiency is improved.**

the *N*-1 security c

the *N*-1 security c

distribution network search method[5] and

scan the whole networ

these methods need to

ti **Efficiency is improved.**
 Analytical expression; Weak link.
 Analytic system can be guaranteed by switching operation after a single
component fault occurs in the distribution network. N-1
contingency analysis of distribution network is an important
means to analyze the safety and reliabilit component fault occurs in the distribution network. *N*-1 contingency analysis of distribution network is an important means to analyze the safety and reliability of distribution network operation, and it is also an import contingency analysis of distribution network is an important
means to analyze the safety and reliability of distribution
network operation, and it is also an important part that can't be
ignored in the process of distribu means to analyze the safety and reliability of distribution
network operation, and it is also an important part that can't be
ignored in the process of distribution network planning. It is of
great significance to the plan network operation, and it is also an important part that can't be
ignored in the process of distribution network planning. It is of
great significance to the planning and operation of distribution
network.
The most convent ignored in the process of distribution network planning. It is of
great significance to the planning and operation of distribution
network.
The most conventional N -1 contingency analysis method is
to search transfer pat great significance to the planning and operation of distribution
network.
The most conventional *N*-1 contingency analysis method is
to search transfer path and analyze whether the load affected by
fault can be transferred network.
The most conventional *N*-1 contingency analysis method is
to search transfer path and analyze whether the load affected by
fault can be transferred when a single component exits, and
then reprocess the verificati The most conventional N -1 contingency analysis method is
to search transfer path and analyze whether the load affected by
fault can be transferred when a single component exits, and
then reprocess the verification resul to search transfer path and analyze whether the load affected by
fault can be transferred when a single component exits, and
then reprocess the verification result to obtain some security
indicators, so as to evaluate the fault can be transferred when a single component exits, and
then reprocess the verification result to obtain some security
indicators, so as to evaluate the security of the distribution
network at a certain load level [3] then reprocess the verification result to obtain some security
indicators, so as to evaluate the security of the distribution
network at a certain load level [3][4]. This method of fault
enumeration needs to analyze and v indicators, so as to evaluate the security of the distribution
network at a certain load level [3][4]. This method of fault
enumeration needs to analyze and verify each component's
fault, it is a multi-cycle process and ve network at a certain load level [3][4]. This method of fault
enumeration needs to analyze and verify each component's
fault, it is a multi-cycle process and very time consuming. With
the attention paid to the planning and enumeration needs to analyze and verify each component's
fault, it is a multi-cycle process and very time consuming. With
the attention paid to the planning and operation of distribution
network in recent years, some model fault, it is a multi-cycle process and very time consuming. With
the attention paid to the planning and operation of distribution
network in recent years, some models and methods considering
the $N-1$ security criterion an the attention paid to the planning and operation of distribution
network in recent years, some models and methods considering
the $N-1$ security criterion and practical constraints of
distribution network have been gradual network in recent years, some models and methods considering
the *N*-1 security criterion and practical constraints of
distribution network have been gradually proposed. The path
search method[5] and *N*-1 scanning method[the *N*-1 security criterion and practical constraints of distribution network have been gradually proposed. The path search method[5] and *N*-1 scanning method[6] can be used to scan the whole network to find a restore p distribution network have been gradually proposed. The path
search method[5] and $N-1$ scanning method[6] can be used to
scan the whole network to find a restore power supply path, but
these methods need to repeat the sea search method[5] and *N*-1 scanning method[6] can be used to
scan the whole network to find a restore power supply path, but
these methods need to repeat the search process and they are
time consuming. The heuristic method scan the whole network to find a restore power supply path, but
these methods need to repeat the search process and they are
time consuming. The heuristic method[7] and capacity
calculation method[8][9] can be used to find these methods need to repeat the search process and they are
time consuming. The heuristic method[7] and capacity
calculation method[8][9] can be used to find *N*-1 contingency
analysis result, these methods are fast but t time consuming. The heuristic method[7] and capacity calculation method[8][9] can be used to find N -1 contingency analysis result, these methods are fast but they are inaccurate. The preprocessing network -method [10] [calculation method[8][9] can be used to find *N*-1 contingency analysis result, these methods are fast but they are inaccurate. The preprocessing network -method [10] [11] can simplify the problem and get the accurate resu

Index Terms—Distribution network; *N*-1 contingency analysis;

Analytical expression; Weak link.

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time consu

calculation 1

analysis resus

Manuscript received XXXX XX, 20XX; revis Index Terms—Distribution network; *N*-1 contingency analysis;

Scanch method[5] a

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time consuming.

Calculation method

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search method[5] and

search method[5] and

search method [5] and

time consuming. T

calculation method [8

manuscript received XXXX XX, 20XX; revised XXX Foundation of Tianjin under Grant 19JCYBJC21300. (*Corresponding author:* The W-1 contingency and F-2. Luo are with Key Laboratory of Same the Meson of Tianjin under Grant 2020 (*Corresponding author:* The preprocessing ne *Manuscript received XXXX XX, 20XX; re*

accepted XXXX XX, 20XX. This work was suppo

Research and Development Program of China und

in part by National Natural Science Foundation of Grant U1866207 and Grant 51207101, and these methods need

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analysis result, these

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epted XXXX XX, 20XX. This work was supported in part by time consuming. T

calculation method [8

analysis result, these

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accepted XXXX XX, 20XX. This work was supported in pa
Research and Development Program of China under Grant
in part by National Natural Science Foundation of China und
Grant U18 Manuscript received XXXX XX, 20XX; revised XXXX XX, 20XX; analysis result, these morepted XXXX XX, 20XX. This work was supported in part by National Key problem and get the accessor and Development Program of China under G mallysis result, these

mallysis result, these

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in part by National

Tianjin Electric Power Company, Tianjin 300171, China (e-mail: zhangtianyu@tju.edu.cn).

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identify the weak links through parallel c
be solved.
In fact, when different components
transfer path may be similar In santicle has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may club ation information: DOI: 10.1775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy System This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content ma
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identif This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may che Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy Sy *N*-1 contingency analysis, the overload problem of components

and lines is seen at the proposal of proposition information: DOI: 10.1775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy Systems

identify the weak l identify the weak links through parallel computing remains to

be solved.

In fact, when different components fail, fault area and

in fact, when different components fail, fault area and

contacted, L_{ij} =1, and when th identify the weak links through parallel computing remains to

the solved.

In fact, when different components fail, fault area and contacted, L_{ij} =1, and v

transformer T_i and voltated, L_{ij} =1, and v

according to be solved.

In fact, when different components fail, fault area and contacted, $L_{i,j} = 1$, and

transfer path may be similar. By constructing incidence matrix Define the elements in

according to the delationship between In fact, when different components fail, fault area and contacted, L
transfer path may be similar. By constructing incidence matrix Define the el
according to the relationship between components, parallel According t
cons msfer path may be similar. By constructing incidence matrix Define the elements in
cording to the relationship between components, parallel According to the demputation can be realized and the repeated fault search can co according to the relationship between components, parallel

according to the definition

computation can be realized and the repeated fault search can

be avoided. At the same time, weak links can be found.

Therefore, th computation can be realized and the repeated fault search can

be avoided. At the same time, weak links can be found. intra-station contact and inter-

contingency parallel analysis of main transformers in

contingency pa be avoided. At the same time, weak links can be found. Intra-station contact and inter-

Christophoe are three sums and the sum intersformers in

distribution networks based on incidence matrix. During the

distribution n

Therefore, this paper proposes an analytical method of N -1

contingency parallel analysis of main transformers in

distribution network based on incidence matrix. During the

M-1 L<sub>A_{UM} L L_{AUM} L

M-1 Contingency anal</sub> contingency parallel analysis of main transformers in

distribution networks based on incidence matrix. During the

M-1 contingency analysis, the overload problem of components

and lines is usually taken into account, an distribution networks based on incidence matrix. During the

N-1 contingency analysis, the overload problem of components

and lines is usually taken into account, and factors such as

voltage, reactive power and network A-1 contingency analysis, the overload problem of components

and lines is usually taken into account, and factors such as

voltage, reactive power and network loss are usually simplified
 $\begin{bmatrix}\n1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 &$ and lines is usually taken into account, and factors such as

voltage, reactive power and network loss are usually simplified

[17]. Therefore, the capacity constraint of main transformers

and the lines is mainly conside voltage, reactive power and network loss are usually simplified

[17]. Therefore, the capacity constraint of main transformers

and tie-lines is mainly considered in this paper.

Firstly, the main transforme incidence mat [17]. Therefore, the capacity constraint of main transformers

and tie-lines is mainly considered in this paper.

Firstly, the main transformer incidence matrix is established.

According to different ways of load transfe and tie-lines is mainly considered in this paper.

Firstly, the main transformer incidence matrix is established.

According to different ways of load transfer, it is divided into

there types contact matrices of load tra Firstly, the main transformer incidence matrix is established.

According to different ways of load transfer, it is divided into

three types, and three types contact matrices of load transfer capacity

the stablished int According to different ways of load transfer, it is divided into
three types, and three types contact matrices of load transfer are

three types, and the eightis of condition of the main diagon
maximum transformers and th three types, and three types contact matrices of load transfer are

the established respectively. Secondly, the capacity matrices of

elements on the main

main transformers and the tie-lines are established, and the rela established respectively. Secondly, the capacity matrices of
main transformers and the tie-lines are established, and the relations, and the matrix elem
meaximum transfor capability (MTC) of the distribution
metrod is giv main transformers and the tie-lines are establistic
maximum transfer capability (MTC) of th
network is obtained through the operation of cc
and capacity matrices, then *N*-1 contingency an
obtained by comparing it with the Example in the method proposed solaring and save the computation of the inter-station of three depacity matrices, then $N-1$ contingency analysis result is B . *Definition of three* depacity matrices, then $N-1$ continge metwork is obtained through the operation of contact matrices

and capacity matrices, then *N*-1 contingency analysis result is

obtained by comparing it with the load that needs transferring.

At the same time, the weak l and capacity matrices, then *N*-1 contingency analysis result is

obtained by comparing it with the load that needs transferring.

At the same time, the weak links of *N*-1 contingency analysis

are identified and the reas obtained by comparing it with the load that needs transferring.

At the same time, the weak links of *N*-1 contingency analysis

are identified and the reasons why the distribution system

doesn't satisfy the *N*-1 reliabi At the same time, the weak links of N -1 contingency analysis metallierd and the reasons why the distribution system by doesn't satisfy the N -1 reliability requirement can also be found indirect by calculating the tran Example is a to provide network and the distribution with the three considering the transformers or tie-lines after transformers and order to facilitate

lines after transformers or tie-lines after transformers and order

A. Main transformer incidence matrix
 A. Main transformers or tellines after transfering. Here, the transfer margin means the proce-

left capacity of main transformers or tie-lines after transferring three

load. Fin Assume that there are *n* substation are *n* substation are *n* substation are *n* substanting the expecting the proposed method.

The method proposed in this paper can avoid complicated is transferred to intra-station pr

From the spectrom of the main transformer solution of the main transformer of main transformers of the main transformer defined in this paper can avoid complicated is transferred to intra-station in fault searching and sa transformers corresponding to each substation are N_1 , N_2 in the substation are *N* in *N*₁ *N*₂ is *N*_N² is the number of all main transformers corresponding in the substation are *N*¹ is an inter-station *N* and He meano phoposed in using paper can avoid complicated in the number of main transformers of main transformers contained in the number of main transformers contained in the number of main transformers contained the method is the computator of the team of the substation result is that affect $N-1$ is transferred to the verification result so as to provide necessary information for the is an inter-station planning and design of di II. MAIN TRANSFORMER FAULT LOAD TRANSFER MODEL

the main transformer T_k and the Main transformer incidence matrix
 Λ

Assume that there are *n* substations in the distribution Considering the high level of

twork num MER FAULT LOAD TRANSFER MODEL

the main transform

between T_k and T_i,

re *n* substations in the distribution

. *n* respectively, the number of main type-C transfer take

the mumber of all main transformers. One time *N N j N N L L L* **EXERUIT LOAD TRANSFER MODEL**

incidence matrix

incidence matrix

are *n* substations in the distribution
 L_{tot} are *n* substations in the distribution
 L_{tot} are *n* substations in the distribution
 L_{tot} i incidence matrix

are *n* substations in the distribution
 Γ ,... *n* respectively, the number of main type-C transfer takes the

dding to each substation are $N_1, N_2 \ldots N_n$, intermediate link for transfer

to the numbe

$$
\sum_{i=1}^{m} N_i = N_m \tag{1}
$$

[18][19]:

\n The number of main transforms contained in lines, it can be calculated by (1):\n
$$
\sum_{i=1}^{m} N_i = N_m \sum_{i=1}^{m} \tag{1}
$$
\n

\n\n The number of real numbers is defined as a number of integers:\n \n- is defined as a number of integers.
\n- is defined

In (2), *L_{ij}* represents the contact relationship between the in transformer T_i and the main transformer T_j . When they are the main transformer T_j , when they are that $L_{i,j} = 1$, and when they are not contacted, as not been fully edited. Content may change prior to final publication. 2
wer and Energy Systems
In (2), L_{ij} represents the contact relationship between the
main transformer T_i and the main transformer T_j . When th as not been fully edited. Content may change prior to final publication. 2
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In (2), $L_{i,j}$ represents the contact relationship between the
main transformer T_i and the main transformer T_j . When t as not been fully edited. Content may change prior to final publication. 2
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In (2), $L_{i,j}$ represents the contact relationship between the
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In (2), L_{ij} represents the contact relationship between the

main transformer T_i and the main transformer T_j . Wh as not been fully edited. Content may change prior to final publication.

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In (2), $L_{i,j}$ represents the contact relationship between the

main transformer T_i and the main transformer T_j . When as not been fully edited. Content may change prior to final publication.

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In (2), $L_{i,j}$ represents the contact relationship between the

main transformer T_i and the main transformer T_j . When *^N ^N N N ^N N*, $L_{i,j} = 1$, and when they are not contacted, $L_{i,j} = 0$.

the elements in main diagonal of L are 0, that is $L_{i,j} = 0$.

the elements in main diagonal of L are 0, that is $L_{i,j} = 0$.

the definition, L is a sym **n** fully edited. Content may change prior to final publication. 2
 L_{Lj} represents the contact relationship between the
 L L_{Lj} represents the contact relationship between the
 L L_{Lj} and the main transforme y edited. Content may change prior to final publication. 2

Systems

y represents the contact relationship between the

primer T_i and the main transformer T_j. When they are

lements in main diagonal of **L** are 0, that fully edited. Content may change prior to final publication.

ergy Systems
 $L_{i,j}$ represents the contact relationship between the

informer T_i and the main transformer T_j . When they are
 $d, L_{i,j}=1$, and when they ar y edited. Content may change prior to final publication.

2 Systems
 L_i represents the contact relationship between the

thermer T_i and the main transformer T_j . When they are
 L_i =1, and when they are not contacted y edited. Content may change prior to final publication.

2 Systems

y represents the contact relationship between the

thermer T_i and the main transformer T_j. When they are

L_i_{ij}=1, and when they are not contacte n fully edited. Content may change prior to final publication. 2

hergy Systems

), $L_{i,j} = 1$, and the main transformer T_j . When they are

unsformer T_i and when they are not contacted, $L_{i,j} = 0$.

the elements in ma

ENERTY CONDUCTS THE MANUSE THE MANUSE CONSULTS AND THE MANUSE CONSULTS IN THE MANUSE CONSULTS AND M O M $L_{N,M}$ I $L_{N,M}$ I $L_{N,M+1}$ $L_{N,M+2}$ I $L_{N,M+3}$ I $L_{N,M}$ I $L_{N,M}$ I $L_{N,M}$ I $L_{N,M}$ I $L_{N,M+2}$ I $L_{N,M+3}$ **EXECUTE:** THE TRANSFORT THE TRANSFORT THE TRANSFORT THE TRANSFORT THE MAIN THE MAIN THE MAIN THE MAIN THE MAIN THE MAIN DETERMING THE MAIN **EVALUAT THE CONFIDENT CONTROVED THE MANGE THE MANGE THE MANGER IN A 10 IN IT (A), I. It is divided into** $N \times N$ **blocks, in which the matrix elements on the main diagonal represent the intra-station relations, and the matr** $\begin{bmatrix} L_{x,y1} & L_{x,yn} \\ L_{x,y1} & L_{x,yn1} \end{bmatrix}$ $\begin{bmatrix} L_{x,yn1} & L_{x,yn1} \\ L_{x,yn2} & L_{x,yn2} \end{bmatrix}$ [Lefter] $\begin{bmatrix} L_{x,y1} \\ L_{x,y2} \end{bmatrix}$

In (3), *L* is divided into $N \times N$ blocks, in which the matrix

elements on the main diagonal In (3), **L** is divided into $N \times N$ blocks, in which the matrix
elements on the main diagonal represent the intra-station
elements on the main diagonal represent the intra-station
relations, and the matrix elements on the In (3), *L* is divided into $N \times N$ blocks, in which the matrix
elements on the main diagonal represent the intra-station
relations, and the matrix elements on the non-main diagonal
represent the inter-station relations.
 elements on the main diagonal represent the intra-station
relations, and the matrix elements on the non-main diagonal
represent the inter-station relations.
B. Definition of three types load transfer ways
The load transfe relations, and the matrix elements on the non-main diagonal
represent the inter-station relations.
B. Definition of three types load transfer ways
The load transformer fault
includes a variety of transfer ways. The load c *B. Definition of three types load transfer ways*
The load transfer in the case of main transformer fault
includes a variety of transfer ways. The load can be transferred
by the main transformer inside the station or outs Ine load transfer in the case of main transformer rault
includes a variety of transfer ways. The load can be transferred
by the main transformer inside the station or outside the station,
and by the main transformer which metudes a variety of transfer ways. The load can be transferred
by the main transformer inside the station or outside the station,
and by the main transformer which is directly connected or
indirectly connected to the mal and by the main transformer which is directly connected or
indirectly connected to the malfunctioning main transformer. In
order to facilitate the analysis and expression of the transfer
process, this paper divides the on

marrectly connected to the maltimictioning main transformer. In
order to facilitate the analysis and expression of the transfer
process, this paper divides the one time of transfer process into
three types according to th process, this paper divides the one time of transfer process into
three types according to the different ways of transfer. The
three types of transfer are defined as follows:
Type-A: the load of the malfunctioning main tr three types according to the different ways of transfer. The
three types of transfer are defined as follows:
Type-A: the load of the malfunctioning main transformer T_i
is transferred to intra-station main transformer T three types of transfer are defined as follows:

Type-A: the load of the malfunctioning main transformer T_i

is transferred to intra-station main transformer T_j ;

Type-B: the load of the malfunctioning main transforme Type-A: the load of the mail uncidentify main transformer T_j ;
 Δ Type-B: the load of the malfunctioning main transformer T_j ;
 Δ Type-B: the load of the malfunctioning main transformer

is transferred to the inte

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. 3
Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CS This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to fi
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This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may che Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy Sy This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may che Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy Sy This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may channel Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energ This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Conter-
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transferred to the intra-station main t is article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may chan the matrix elements on the matrix elements of the main transformer T_{k1} or T_{k2} , that s This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content n
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transferred to the intra-station main transfor

which belongs to type-A; the load can be tr

inter-station main transformer T_j , which belon

load can be transferred Example that been accepted for publication in a future issue of this journal,

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red to the intra-station main transformer T_{k1} or T_{k2}

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formation: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Ener
red to the intra-station main transformer T_k or

compose the type-B transfer contact matrix *^B*: 1, 1 1 1, 1 2 1, 1, 1 1 1, 1 2 1, 1 1,1 1 1, 1 1 1, 1 2,1 1 2, 1 1 2, 1 2,1 1 2, 1 , 1 1 , 1 2 0 0 *N N N N N N N ^N L L L ^L L L L B* L L L L L L M O M M O M L L L In (5), the *ⁱ*-th row *^j*-th column element of *^B* is *^bi*,*j*, *^bi*,*^j* represents whether T*^j* can carry the load of T*ⁱ* in type-B transfer when T*ⁱ* fails. If so, *^bi*,*j*=1, otherwise *^bi*,*j*=0. Type-A and type-B both transfer load directly through LL LL L LM O M L M O M

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wer and Energy Systems
that satisfies $a_{i,k}=b_{k,j}=1$, then the element in *i*-th row and *j*-th
column of *C* is equal to 1, i.e. $c_{i,j}=1$. So, the as not been fully edited. Content may change prior to final publication. 3
wer and Energy Systems
that satisfies $a_{i,k}=b_{k,j}=1$, then the element in *i*-th row and *j*-th
column of *C* is equal to 1, i.e. $c_{i,j}=1$. So, the as not been fully edited. Content may change prior to final pu
wer and Energy Systems
that satisfies $a_{i,k}=b_{k,j}=1$, then the element in *i*-th
column of *C* is equal to 1, i.e. $c_{i,j}=1$. So, the eleme
expressed as:
 $c_{i,j}=$ where the mass of the proof of final publication.
 $\begin{aligned}\n &\text{3}\n \end{aligned}$
 $\begin{aligned}\n &\text{5}\n \end{aligned}$ =1, then the element in *i*-th row and *j*-th
 $\begin{aligned}\n &\text{6}\n \end{aligned}$, i.e. $c_{i,j} = 1$. So, the element of *C* can be
 $\begin{aligned}\n$ Content may change prior to final publication. 3
 j=1, then the element in *i*-th row and *j*-th

1 to 1, i.e. $c_{i,j}$ =1. So, the element of *C* can be
 $c_{i,j}$ =1- $\prod_{k=1}^{N} (1 - a_{i,k} b_{k,j})$ (7)

be calculated by *A* a ent may change prior to final publication. 3

, then the element in *i*-th row and *j*-th

1, i.e. $c_{i,j}$ =1. So, the element of *C* can be
 $= 1 - \prod_{k=1}^{N} (1 - a_{i,k} b_{k,j})$ (7)

calculated by *A* and *B*.

CY ANALYSIS OF MA not been fully edited. Content may change prior to final publication.
 C and *Energy Systems*
 C at satisfies $a_{i,k} = b_{k,j} = 1$, then the element in *i*-th row and *j*-th

plumn of **C** is equal to 1, i.e. $c_{i,j} = 1$. S

$$
c_{i,j} = 1 - \prod_{k=1}^{N} \left(1 - a_{i,k} b_{k,j} \right)
$$
 (7)

network can carr

(MTC) of the dis

transformer. Sup

is $TM=[TM_1 \cdots T_I$

is $R=[R_1 \cdots R_i \cdots$
 $T=[T_1 \cdots T_i \cdots T_N]^T$
 $T=[R_1 T_1 \cdots R_i T_i]$
 \bullet $T=[R_1 T_1 \cdots R_i T_i]$
 \bullet $T=[R_1 T_1 \cdots R_i T_i]$
 \bullet $T=[R_1 \cdots R M_i]^T$. As

Hadamard pr 17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy Systems

station main transformer T_{k1} or T_{k2}, that satisfies $a_{i,k}=b_{k,j}=1$, then the electric

A; the load can be transferred to the column of C is equal to or threat-station mannihindrino mannihindrino that is only and satisfied to the mean set that is the signal of L and Section mann transformer T_k (and the inter-station mannihindrino the inter-station of $C_k = 1 - \prod_{k=1}^{N$ Leading to the sequal to 1, i.e. $c_{i,j} = 1$. So, the element

is to type B; the expressed as:

the substation

transformer T_j

the substation

Therefore, C can be calculated by A and B.

Lepresents the III. N-1 CONTINGE ongs to type-B; the expressed as:
 $c_{i,j} = 1 - \prod_{k=1}^{N} (1 - a_{i,k}b_{k,j})$
 \therefore Therefore, C can be calculated by A and B.

S.
 \therefore Therefore, C can be calculated by A and B.

substation. These *n*
 \therefore Herefore, C can b Therefore, C can be calculated by A and L

L represents the

L represents the

III. N-1 CONTINGENCY ANALYSIS OF MAIL

station. These *n*
 ΔL verification principle

type-A transfer

When a main transformer failure occu (4) is $R = [R_1 \cdots R_i \cdots R_N]^T$, main transformer load rate matrix is *^N N N ^N L L ^L* N-1 verification, and the transfer gap of T_i , which means the amount of load that can't be transferred, is equal to $|RM_i|$, the or $\begin{bmatrix}\n\frac{1}{N}\n\end{bmatrix}$
 $\begin{bmatrix}\n\frac{1}{N}\n\end{bmatrix}$ and the rain transformer failure occurs,
 $\begin{bmatrix}\n\frac{1}{N}\n\end{bmatrix}$ or $\begin{bmatrix}\n\frac{1}{N}\n\end{bmatrix}$ or $\begin{bmatrix}\n\frac{1}{N}\n\end{bmatrix}$ or $\begin{bmatrix}\n\frac{1}{N}\n\end{bmatrix}$ or $\begin{bmatrix}\n\frac{1}{N}\n\end{$ We all the other tallule occurs, the $\frac{1}{N+1}$
 $\$ 0
 $\begin{bmatrix}\nL & 0 & \text{capacity that other main transforms}\n\end{bmatrix}$
 $\begin{bmatrix}\nL & 0 & \text{network can carry is called the maximum transfer}\n\end{bmatrix}$
 $\begin{bmatrix}\nM' & 0 & \text{instructor} \\
M & 0 & \text{is } \mathbf{M} = [M_1 \cdots M_N \cdots M_N]^T, \text{ main transform}\n\end{bmatrix}$
 $\begin{bmatrix}\nL & 0 & \text{instructor} \\
M & 0 & \text{is } \mathbf{M} = [M_1 \cdots M_N \cdots M_N]^T, \text{ main transform}\n\end{bmatrix}$
 $\begin{bmatrix}\nL &$ LATE C of the distribution system centrer of the maximum transformer. Suppose the maximu M O M L M O M For $L_{N+1, N+1}$ L $L_{N+1, N+2}$
 $\begin{array}{c|c|c|c|c|c} \hline \text{L} & \text{L}$ M O M C ANDERED (A The CHAPTER (A THE CHAPTER CHAPTER DRIFT AND THE CHAPTER CHAPTER (SURVEY)

M O M T=[T, ..., T, ..., T, ..., T, ..., T, ..., T, ..., T, ..., Then main transformer load

(4) is $\mathbf{R} = \mathbf{R} \cdot \mathbf{R} \cdot \math$ as not been fully edited. Content may change prior to final publication

wer and Energy Systems

that satisfies $a_{i,k}=b_{k,j}=1$, then the element in *i*-th row

column of *C* is equal to 1, i.e. $c_{i,j}=1$. So, the element of and Energy Systems

and Energy Systems

at satisfies $a_{i,k}=b_{k,j}=1$, then the element in *i*-th row and *j*-th

lumn of *C* is equal to 1, i.e. $c_{i,j}=1$. So, the element of *C* can be

pressed as:
 $c_{i,j}=1-\prod_{k=1}^{N}(1-a_{i,k}b$ calculate that satisfies $a_{ik} = b_{kj} = 1$, then the element in *i*-th row and *j*-th
column of *C* is equal to 1, i.e. $c_{ij} = 1$. So, the element of *C* can be
expressed as:
 $c_{i,j} = 1 - \prod_{k=1}^{N} (1 - a_{i,k} b_{k,j})$ (7)
Therefore, that satisfies $a_{i,k}=b_{k,j}=1$, then the element in *i*-th row and *j*-th
column of *C* is equal to 1, i.e. $c_{i,j}=1$. So, the element of *C* can be
expressed as:
 $c_{i,j}=1-\prod_{k=1}^{N}(1-a_{i,k}b_{k,j})$ (7)
Therefore, *C* can be calcu column of *C* is equal to 1, i.e. $c_{i,j}$ =1. So, the element of *C* can be
expressed as:
 $c_{i,j} = 1 - \prod_{k=1}^{N} (1 - a_{i,k}b_{k,j})$ (7)
Therefore, *C* can be calculated by *A* and *B*.
III. *N*-1 CONTINGENCY ANALYSIS OF MAIN TRAN expressed as:
 $c_{i,j} = 1 - \prod_{k=1}^{N} (1 - a_{i,k}b_{k,j})$ (7)

Therefore, *C* can be calculated by *A* and *B*.

III. *N*-1 CONTINGENCY ANALYSIS OF MAIN TRANSFORMER
 A. Verification principle

When a main transformer failure oc $\prod_{k=1}^{N} (1 - a_{i,k} b_{k,j})$ (7)
lated by *A* and *B*.
NALYSIS OF MAIN TRANSFORMER
failure occurs, the maximum load
transformers in the distribution
l the maximum transfer capability
ystem centered on the failed main
aximum $\begin{aligned}\n &\text{and} \quad \text{and} \quad E = 1 - \prod_{k=1} (1 - a_{i,k} b_{k,j})\n \end{aligned}$

CCY ANALYSIS OF MAIN TRANSFORMER

ple

former failure occurs, the maximum load

main transformers in the distribution

called the maximum transfer capability

ti $T = [T_1 \cdots T_i \cdots T_N]^T$, then main transformer load matrix is $LM=R$ an be calculated by *A* and *B*.

NGENCY ANALYSIS OF MAIN TRANSFORMER

principle

ransformer failure occurs, the maximum load

her main transformers in the distribution

y is called the maximum transfer capability

stribu • $T=[R_1T_1 \cdots R_iT_i \cdots R_NT_N]^T$, main transformer margin matrix is ANALYSIS OF MAIN TRANSFORMER

er failure occurs, the maximum load

t transformers in the distribution

d the maximum transfer capability

system centered on the failed main

maximum transformer capacity matrix
 T , main $R^2 = R - R$ $T = [R^1_1 \cdots R^1_N]^T$. The symbol ' \circ ' represent ALYSIS OF MAIN TRANSFORMER

indure occurs, the maximum load

ransformers in the distribution

the maximum transfer capability

tem centered on the failed main

intimum transformer capability matrix

main transformer load A. Verification principle
When a main transformer failure occurs, the maximum load
capacity that other main transformers in the distribution
network can carry is called the maximum transfer capability
(MTC) of the distrib $RM_i \cdots RM_N$ ^T. As for the *i*-th element of **RM**, if $RM_i \ge 0$, that on principle
in transformer failure occurs, the maximum load
t other main transformers in the distribution
carry is called the maximum transfer capability
distribution system centered on the failed main
Suppose the maximu When a main transformer failure occurs, the maximum load
capacity that other main transformers in the distribution
network can carry is called the maximum transfer capability
network from the failed main
transformer. Supp capacity that other main transformers in the distribution
network can carry is called the maximum transfer capability
netWork of MTC) of the distribution system centered on the failed main
transformer. Suppose the maximum *^N*-1 verification, and the transfer gap of T*i*, which means the as $IM=[IM_1 \cdots IM_i \cdots IM_N]^t$, main transformer capacity matrix
is $R=[R_1 \cdots R_i \cdots R_N]^T$, main transformer load rate matrix is
 $T=[T_1 \cdots T_i \cdots T_N]^T$, then main transformer load matrix is $LM=R$
 $T=[R_1T_1 \cdots R_iT_i \cdots R_N^T]^T$, main transfo is $\mathbf{R}=[R_1 \cdots R_i \cdots R_N]^T$, main transformer load rate matrix is $\mathbf{Z}=[T_1 \cdots T_i \cdots T_N]^T$, then main transformer load matrix is $\mathbf{L}M=R$
 \bullet $\mathbf{T}=[R_1T_1 \cdots R_iT_i \cdots R_NT_N]^T$, main transformer margin matrix is
 $\mathbf{R}^$ **ER-R**^o **T**=[R'₁····R'₁···R'₁/··^R₁/^T. The symbol '· ' represents the ddamard product operation. Suppose **RM=TM-LM**=[RM₁···
 A_1 ····R M_N]^T. As for the *i*-th element of **RM**, if $RM_i \ge 0$, that $A_1 \cdots RM_N$ **Hadamard product operation.** Suppose $RM = TM-LM = [RM_1 \cdots RM_i \cdots RM_N]^T$. As for the *i*-th element of RM_i , if $RM_i \ge 0$, that means when the main transformer T_i fails, the MTC of the distribution network is greater than or equal *RAI*, $\cdots R M_N$ ^T. As for the *i*-th element of **RM**, if $RM_i \geq 0$, that $RM_i \cdots RM_N$ ^T. As for the *i*-th element of **RM**, if $RM_i \geq 0$, that means when the main transformer T_i fails, the MTC of the distribution network *KM_i* ••• *KM_N*] •. As for the *t*-th element of *KM*, if *KM_i* \neq 0, that distribution network is greater than or equal to the load of T_{*i*} and T_{*i*} saisfy the *N*-1 reliability requirement, that is to say, means when the main transformer T_i tails, the MTC of the distribution network is greater than or equal to the load of T_i , and T_i satisfy the $N-1$ verification. If $RM_i < 0$, then T_i can't pass the $N-1$ verificatio

B. Calculation of maximum transfer capability

capacity constraint of main transformers and tie-lines, the key The MTC can be calculated by calculating the MTC of three of $N-1$ contingency analysis is to calculate the MTC of the three load of the distribution network is known, considering the distribution network is greater than or equal to the l
and T_i satisfy the N -1 reliability requirement, that is
can pass the N -1 verification. If RM_i <0, then T_i can
 N -1 verification, and the transfer gap of T_i Exercisely and summing the results. When the

tribution network is known, considering the

int of main transformers and tie-lines, the key

ney analysis is to calculate the MTC of the three

spectively.

ine capacity matr the *N*-1 verification. If RM_i \leq 0, then T_i can't pass the

fication, and the transferr gap of T_i , which means the

fication, and the transferr gap of T_i , which means the

f load that can't be transferred, is e werification, and the transfer gap of T_b , which means the
unt of load that can't be transferred, is equal to $|RM_i|$, the
rence between the MTC and load of T_b .

Adculation of maximum transfer capability

e MTC can be c Determined that can interest and the transferred in the transfer of load that can't be transferred, is equal to $|RM_i|$, the

between the MTC and load of T_i.

ulation of maximum transfer capability

TC can be calculated qual to $|RM_i|$, the

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the MTC of three

esults. When the

considering the

tie-lines, the key

MTC of the three

L L TCM_{NN}

M O M

L L TCM_{NNN}

M O

When there is no tie-line between T_i and T_j , $TCM_{ij}=0$,
otherwise $TCM_{ij}=0$. Therefore, TCM also reflects the contact The sum of the sum of the sum of the interactions is a set of the intra-station load its capacity is large enough to support the intra-station load transfer [20]. Therefore, the capacity contrains and its capacity of defi TCM_{NENSER} ET TCM_{NENSER} TCM_{NENSER} (C)

TECH_{NENSER} TCM_{NENSER} (C)

TCM_{NENSER} TCM_{NENSER} TCM_{NENSER} (C)

TCM_{NENSER} TCM_{NENSER} TCM_{NENSER} TCM_{NENSER} TCM (B)

In (8), the *i*-th row *j*-th column element of FORE THE THE THE INTERT CONTROLLED THE THE THE THE THE THE THANGET THE STATION OF THE IS NOT CONSULTED THE INTERTATION OF CONSIDERATION OF CONSIDERATION (THE IS NOT CONSIDER THE IS NOT CONSIDER THE CONSIDERATION OF CONSID (1) Type-A transfer matrix

(1) Type-A transfer matri

then: *B B*

 $\begin{bmatrix}\n0 & \frac{M}{R_{i,j+1}} & 0 & M & 1 & 0 & M \\
\hline\n\frac{1}{R_{i,j+1}} & 1 & \frac{1}{R_{i,j}} & \frac{1}{R_{i,j+1}} & \frac{1}{R_{i,j+1}} & \frac{1}{R_{i,j}} & \frac{1}{R_{$ T_j and the capacity is S_{ij-b} , $BTM_{ij} = \min\{b'_{ij}, S_{ij-b}\}\.$ As for type-B *i*, $\frac{1}{\left[\begin{array}{l}N\end{array}\right]}$ $\left[\begin{array}{l}N\end{array}\right]$, $\$ **EXECUTE THE CONSTRANS AND THE SET UP AND THE CALL AND THE CONSTRANT CONDUCT AND THE CALL ACCORD BY A THE SIDE CONDUCT AND THE CALL ACCORD BY A THE CALL AND THE CALL AND THE CALL AND THE CALL ACCORD BY A THE CALL AND THE** Considering the capacity constraint of the actual tie-line, the set all tie-line, the set all tie-line of $\mathbf{B}^T M$ is $\begin{bmatrix} \mathbf{K}_{l,m+1,m} & \mathbf{K}_{l,m+2,m+1} \\ \hline \mathbf{K}_{l,m+2,m} & \mathbf{K}_{m+2,m+1} & \mathbf{K}_{m+2,m+2,m+2,m+2,m+2,m+2,m+2,m+2,m+2,m+$ $\begin{bmatrix} \frac{R_{i}L_{y_{1},y_{2,1}}}{L} & \frac{R_{y_{1}}L_{y_{1},y_{2,1}}}{L} & \frac{R_{y_{1}}L_{y_{1},y_{2,1}}}{L} & \frac{R_{y_{1}}L_{y_{1},y_{2,1}}}{L} & \frac{R_{y_{1},y_{1}}L_{y_{1},y_{1}}}{L} & 0 & \frac{M}{L} \\ \frac{M}{R_{i}L_{y_{1}}L} & \frac{M}{L_{y_{1},L_{y_{1},y_{1}}}} & \frac{M}{L} & \frac{M}{L_{y_{1},y_{1}}L_{y_{1},y_{2,1}}}} &$ $\{i,j, S_{ij-b}\}.$ The N o M and N of N of $\overline{R}_{N,n}$, $L_{N,n+1}$ is $R_{N,n}$, $L_{N,n+2}$ is $\overline{R}_{N,n}$, $L_{N,n+1}$ is $\overline{R}_{N,n}$, $L_{N,n+2}$ is $\overline{R}_{N,n}$ or $\overline{R}_{N,n}$ is Type-C transfer matrix is established as:

 $\begin{array}{c|c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{cccc} \text{N} \\ \text{N} \end{array} & \begin{array}{cccc} \text{N} \\ \text{N} \end{array} & \begin{array}{cccc} \text{N} \\ \text{N} \end{array} \\ \begin{array}{c} \begin{array}{cccc} \text{N} \\ \text{N} \end{array} & \begin{array}{cccc} \text{N} \\ \text{N} \end{array} \\ \begin{array}{cccc} \text{N} \\ \text{N} \end{array} & \begin{array}{cccc} \text{N} \\ \text{N} \end{array} \\ \begin{array}{c} \text{N} \\ \text$ *CTM_{N,A}* L *CTM_{N,NI}* (*CTM_{N,NI+1}* L *CTM_{N,NI+1}* L *CT*

 $\frac{1}{\sqrt{2}}$
 $\frac{1}{\sqrt{2}}$ M

MAXNET UP THANGEND IN THE CALL TRIMATE TRIMATE TRIMATE TRIMATE THE CALL TRIMATE OF **BTM** is BTM_{is},

and amount that the inter-station main

in type-B transformer T_I child, the *i*-th row *j*-th column

in type-B tr L $\begin{vmatrix} 1 & M & 0 \ 0 & 0 \end{vmatrix}$

L $\begin{vmatrix} 1 & 0 \ 0 & 0 \end{vmatrix}$

L $\begin{vmatrix} 1 & 0 \ 0 & 0 \end{vmatrix}$

L $\begin{vmatrix} 1 & 0 \ 0 & 0 \end{vmatrix}$

L $\begin{vmatrix} 1 & 0 \ 0 & 0 \end{vmatrix}$

L $\begin{vmatrix} 1 & 0 \ 0 & 0 \end{vmatrix}$

L $\begin{vmatrix} 1 & 0 \ 0 & 0 \end{vmatrix}$

L $\begin{vmatrix} 1 & 0 \$ **Example 1** R_{M1} **Example 1** R_{M2} **Example 1** R_{M2} **Example 1** R_{M3} **Example 1** R_{M4} S_{ij-c} , $CTM_{i,j}$ =min{ c [']_{ij}, S_{ij-c} }. As for type-*R_{ivisi} i* $\frac{R_{y_1, y_2, y_{t+1}}}{N}$ **i** *L K_iC₂*, *C*_{*i*} *k*_{*S*^{*i*}_{*C*}_{*l*} *i*_{*l*} *i*_{*l*} *l k*_{*Sik*_{*C*} *l k*_{*M*}*l l l l l k*_{*Ml*} *k*_{*S*}*i*_{*k*} *l k*_{*s*}*i*_{*k*} *l*}} transformer T*^k* in the *^m*-th substation which satisfy *^ai*,*k*=*bk*,*j*=1. Considering all the possible T_{*k*, *S_{ij}*-*c* can be expressed as:
 $S_{ij-c} = \sum_{k=N_{(m-1)}=1, k\neq j}^{N_{m-1}} a_{i,k} \cdot b_{k,j} \cdot C_{i,j}$ can be expressed as the load amount that the inter-station main transformer T_{*j*} can carry in} by *J*-th column element of \mathbf{I}
amount that the inter-
rry in type-C transfer when \mathbf{I}
line is sufficient. If there
for type-C transfer, $CTM_{i,j}$ =
 \mathbf{I} , \mathbf{I} for type-C transfer and \mathbf{I} , S_{ij-c} . As *r j*-th column element of *C*' is *c*^{*i*_i, *c*^{*i*}_i amount that the inter-station main y in type-C transfer when T_i fails and the e is sufficient. If there is no tie-line type-C transfer, $CTM_{i,j}=0$. If there is} in (15), the i -th fourth counting entered of the substation and the capacity of the tie-line is sufficient. If there is no tie-line between T_i and T_j for type-C transfer when T_i fails and the capacity of the tie-l represents the load amount that the line-station
transformer T_j can carry in type-C transfer when T_i fails
capacity of the tie-line is sufficient. If there is no
between T_i and T_j for type-C transfer, $CTM_{i,j}=0$. I Interministic of the trial surfact the sufficient. If there is no tie-line
pacity of the trie-line is sufficient. If there is the summarized in the summarized in the m-th substation, there expectly is
c. $CTM_{i,j} = \min\{c_{i,j},$ capacity on the te-line is suitedent. It liest is no de-line
between T_i and T_j for type-C transfer, CTM_{iq}=0. If there is
tie-line between T_i and T_j for type-C transfer and the capacity is
 S_{ij-c} , CTM_{iq}=min{ c Fine between Y_i and Y_j for type-C transfer and the capacity is
 c_r CTM_i_i=min{ $c'_{i,j},S_{ij-c}$ }. As for type-C transfer, suppose T_i

cated in the *m*-th substation, there needs to be a main

nsformer T_k in the S_{ij-c} , CTM_{Lj}-Hill (C_{Lj}, Sy_c_C, As for type-C ualister, suppose 1
located in the *m*-th substation, there needs to be a main
transformer T_k in the *m*-th substation which satisfy $a_{i,k}=b_{k,j}=1$
Considering all th **transfer,** $CTM_{i,j}=0$. If there is

be-C transfer and the capacity is

for type-C transfer, suppose T_i

in, there needs to be a main

tation which satisfy $a_{i,k}=b_{k,j}=1$.
 S_{ij-c} can be expressed as:
 $k \cdot b_{k,j} \cdot TCM_{k,j}$ matrix when T_i fails and the

t. If there is no tie-line

fer, $CTM_{i,j}=0$. If there is

ransfer and the capacity is

pe-C transfer, suppose T_i

rere needs to be a main

1 which satisfy $a_{i,k}=b_{k,j}=1$.

an be expressed a cient. If there is no tie-line
ransfer, $CTM_{i,j}=0$. If there is
-C transfer and the capacity is
r type-C transfer, suppose T_i
there needs to be a main
tition which satisfy $a_{i,k}=b_{k,j}=1$.
 y_{j-c} can be expressed as:
 $\cdot b$ fer, $CTM_{i,j}=0$. If there is
ransfer and the capacity is
pe-C transfer, suppose T_i
are needs to be a main
i which satisfy $a_{i,k}=b_{k,j}=1$.
an be expressed as:
 $\cdot TCM_{k,j}$ (14)
substation where the main
s, when considering t

$$
S_{ij-c} = \sum_{k=N_{(m-1)\sum}+1, k\neq i}^{N_{m\Sigma}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j}
$$
 (14)

 $CTM_{i,j}$ =min{*c*[']_{*i,j*},*S*_{*ij*-*c*}}.

tie-line between
$$
T_i
$$
 and T_j for type-C transfer and the capacity is
\n S_{ij-c} , $CTM_{ij}=\min\{c'_{ij},S_{ij-c}\}$. As for type-C transfer, suppose T_i
\nlocated in the *m*-th substitution, there needs to be a main
\ntransformer T_k in the *m*-th substitution which satisfy $a_{i,k} = b_{k,j} = 1$.
\nConsidering all the possible T_k , S_{ij-c} can be expressed as:
\n
$$
S_{ij-c} = \sum_{k=N_{(m-1)E}+1,k\neq i}^{N_{m-1}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j}
$$
(14)
\nin (14), *m* is the serial number of the substitution where the main
\ntransformer T_i is located.
\nAccording to the above analysis, when considering the
\ncapacity constraint of the actual tie-line, the element of *CTM* is
\n $CTM_{ij}=\min\{c'_{ij},S_{ij-c}\}.$
\nAfter calculating the three kinds of transfer matrices, total
\ntransfer matrix can be calculated:
\n
$$
\begin{bmatrix}\nTC_{1,1} & LC_{1,j} & LC_{1,n} \\
M & 0 & M & 0 \\
N & 0 & M & 0\n\end{bmatrix}
$$
\n $TC = ATM + BTM + CTM = \begin{bmatrix}\nTC_{1,1} & LC_{1,j} & LC_{1,n} \\
M & 0 & M & 0 \\
TV_{n,1} & LC_{n,j} & LC_{n,n}\n\end{bmatrix}$ (15)
\nIn (15), the *i*-th row *j*-th column element of *TC* is $TC_{i,j}$, $TC_{i,j}$
\nrepresents the load amount that the main transformer T_j can
\ncarry when T_i fails.
\nIt is noted that when the main transformer T_i fault exists, the
\ninter-station main transformer T_j may carry the load both in

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Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy is
type-B and type-C trans and TC_{ij} may be greater than R'_{j} , the margin of the main **j** in a future issue of this journal, but has not been fully edited. Content may
 j (*j* , *j* , *j* , *j* , *j* , *j* , *j* , *i* , *i* , *j* , *i* , This article has been accepted for publication in a future issue of this journal, but has not
Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power an
type-B and type-C transfer. For example, in F ublication in a future issue of this journal, but has not been fully edited. Content may change $5/CSEEJPES.2021.01490$, CSEE Journal of Power and Energy Systems

For example, in Fig. 1, when T_i capacity of the main transf for publication in a future issue of this journal, but has not been fully edited. Content may change prior to

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sfer. For example, in Fig. 1, when T_i Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy System

type-B and type-C transfer. For example, in Fig. 1, when T_i capacity of the m

fails, T_j can carry the load of T_i in *TC'* represents the load amount that other main transformers as been accepted for publication in a future issue of this journal, but has not been fully edited. Content
 TM C L TAT/775/CESED *TM* Capacity Content and From Example, in Fig. 1, when T_i capacity Systems

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\n- n accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to: DOI: 10.17775/CSEEPPES.2021.01490, CSEE Journal of Power and Energy Systems
\n- e-C transfer. For example, in Fig. 1, when T_i capacity of the main transformer T_j is try the load of T_i in type-B or type-C transfer. So limiting the increment of the MTC and the r of double counting between *BTM_{ij}* and *CTM_{ij}*, contingency analysis of the main transform
\n- be greater than *R'*, the margin of the main
\n- so **TC** should be modified:
\n- When main transformer T_i fails, the inter-station transfer (including type-B
$$
TC'
$$
 ¹ ¹

 $TC'_{i,j}$ =min{ $TC_{i,j},R'_{j}$ }. The sum of the elements in *i*-th row of fails, T_i can carry the load of T_i in type-B or type-C transfer. So limiting the increment of the M1

there may be part of double counting between BTM_{ij} and CTM_{ij} , contingency analysis of the main

transformer T_i there may be part of double counting between *BTM_{is}* and *CTM_{is}*, contingency and

and *TC_{is}* may be greater than *R_j*, the margin of the main

transformer T_j. So *TC* should be modified:
 $TC'_{1s} \perp TC'_{1s} \perp TC'_{$ *^k i k N k* $TC' = \begin{bmatrix} TC'_{i,j} & L & TC'_{i,j} & L & TC'_{i,j} \\ M & 0 & M & 0 & M \\ TC'_{n,j} & L & TC'_{n,j} & L & TC'_{n,j} \end{bmatrix}$ (16) between T_i and T_j is:

In (16), the *i*-th row *j*-th column element of *TC'* is *TC'_{is}*,

In (19), *m* is the serial number
 $T_{$ $\begin{bmatrix}\n\mathbf{R}^T = \begin{bmatrix}\n\mathbf{K}_{i,1} & \mathbf{L}^T & \mathbf{C}_{i,j} & \mathbf{L}^T & \mathbf{C}_{i,j} \\
\mathbf{M} & 0 & \mathbf{M} & 0 & \mathbf{M} \\
\mathbf{C}_{n,1} & \mathbf{L}^T & \mathbf{C}_{n,j} & \mathbf{L}^T & \mathbf{C}_{n,j}\n\end{bmatrix}\n\end{bmatrix}$

In (16), the *i*-th row *j*-th column element of \mathbf{TC}' $\begin{bmatrix}\n\frac{1}{TC'}_{n,1} & \frac{1}{TC'}_{n,2}\n\end{bmatrix}$ $\begin{bmatrix}\nT^{n} & \frac{1}{LC'}_{n,3}\n\end{bmatrix}$ $\begin{bmatrix}\nTC_{n,1} & \frac{1}{LC'}_{n,3}\n\end{bmatrix}$
 $\begin{bmatrix}\nTC_{n,2}R_{i}\n\end{bmatrix}$, $\begin{bmatrix}\nTC_{n,1} & \frac{1}{LC'}_{n,3}\n\end{bmatrix}$
 $\begin{bmatrix}\nTC_{n,1}R_{i}\n\end{bmatrix}$, $\begin{bmatrix}\nTC_{n,2}R$ If $U_{n,i} = \begin{bmatrix} 1 & 1 & 1 \\ 2 & 1 & 1 \\ 3 & 2 & 3 \end{bmatrix}$ In (19), the i-th row *j*-th column element of **TC'** is $TC'_{i,j}$. In (19), m is the serial num
 ITC' $i_j = \min\{TC_{i,j}, R'_{j}\}$. The sum of the elements in *i*-th row of
 ITC In (16), the *i*-th row *j*-th column element of *TC* is *Ti*
 TC $_{i,j}$ =min{*TC*<sub>*i,jRj*}. The sum of the elements in *i*-th row
 TC represents the load amount that other main transform

can carry when T_i fai</sub>

$$
TM = TC'[1 \ L \ 1 \ L \ 1]^T
$$

= $\left[\sum_{k=1}^{N} TC'_{1,k} \ L \sum_{k=1}^{N} TC'_{i,k} \ L \sum_{k=1}^{N} TC'_{N,k} \right]^T$ (17) $TCM =$
 $\left[\begin{array}{ccc} 1 & -1 \\ -1 & -1 \end{array} \right]$

The inter-state of The Calculated:

Inter-state and amount that other main transformers
 $I = TC'[1 \perp 1 \perp 1]^T$
 $= [\sum_{k=1}^{N} TC']_{1,k} \perp \sum_{k=1}^{N} TC']_{1,k} \perp \sum_{k=1}^{N} TC']_{1,k}$
 $= [\sum_{k=1}^{N} TC']_{1,k} \perp \sum_{k=1}^{N} TC']_{1,k} \perp \sum_{k=1}^{N} TC']$ The weak link is the part of the distribution network is the part of the distribution and the capacity of main transformers and the capacity of main transformers and the capacity of the weak links and then take targeted
 EXECUTE: The weak influence on the *N*-1 contingency analysis result, such as
 T_I fails. Considering all cases
 $T_M = T C'[1 \text{ L} 1 \text{ L} 1]^T$
 $= [\sum_{k=1}^{N} T C'_{1,k} \text{ L} \sum_{k=1}^{N} T C'_{1,k}]^T$
 $= [\sum_{k=1}^{N} T C'_{1,k} \text{ L} \sum_{k=1}^{$ TM = TC ^V_{$_{k1}$} L $\sum_{k=1}^{N} TC'_{i,k}$ L $\sum_{k=1}^{N$ $I = \begin{bmatrix} \sum_{k=1}^{N} TC_{1,k} & L & \sum_{k=1}^{N} TC_{1,k} & L & \sum_{k=1}^{N} TC_{1,k} \end{bmatrix}^T & \begin{bmatrix} (17) & \text{max}_{-1} & L & \text{max}_{N} & \text{max}_{N} \\ \sum_{k=1}^{N} IC_{1,k} & L & \sum_{k=1}^{N} IC_{1,k} \end{bmatrix}^T & \begin{bmatrix} \text{max}_{N} & 1 & \text{max}_{N} & \text{max}_{N} \\ \text{matrix}_{N} & 0 & 1 & \text{max}_{N} \\ \text{matrix}_{N} & 0 & 1 & \text{$ $\begin{bmatrix}\n-\frac{1}{k} & \frac{1}{k} & \frac{1}{$ In (17), the *i*-th element of **TM** represents the MTC of the

in Section distribution network when T_i fails.

in Section and Lie is the relationship between **TM** and LM described

in Section III-A, N-1 contingency anal distribution network when T_i fails.

According to the relationship between **TM** and **LM** described

in Section III-A, N-1 contingency analysis result of all main

transformers can be obtained.

IV. IDENTIFICATION OF WEA According to the relationship between *TM* and *LM* described
in Section III-A, *N*-1 contingency analysis result of all main
transformers can be obtained.
IV. IDENTIFICATION OF WEAK LINKS
The weak link is the part of the *A.* Capacity of main transformers and the main transformers and be obtained.
 A. N-1 contingency analysis result of all matrix transformers can be obtained.
 A. CAPATIFICATION OF WEAK LINKS

The weak link is the part IN THE WEAT THE CALUTE TO THE THE THE TRACHT AND THE TRANS THE WEAT AND THE WEAT AND THE WEAT AND THE WAS THE WEAT AND THE THE VEONES IN EXERCISE THE MAIN THE CONDUCT ON THE THE MAIN THE CONDUCT ON THE TRANSFORM IS THE MA IV. IDENTIFICATION OF WEAK LINKS
The weak link is the part of the distribution network that has
a great influence on the *N*-1 contingency analysis result, such as
the capacity of main transformers and the capacity of te-The weak link is the part of the distribution network that has
a great influence on the *N*-1 contingency analysis result, such as
the capacity of main transformers and the capacity of tie-lines.
It is an important work i The weak link is the part of the distribution network that has

a great influence on the $N-1$ contingency analysis result, such as

the capacity of main transformers and the capacity of tie-lines

It is an important work ak link is the part of the distribution network that has

thence on the *N*-1 contingency analysis result, such as

thence on the *N*-1 contingency analysis result, such as

free the weak links and the capacity of tie-lin eak link is the part of the distribution network that has

fillence on the N-1 contingency analysis result, such as

fillence or the N-1 contingency and the rangement to

trive of main transformers and the capacity of tie

 $\mathbf{F} = \mathbf{R} \cdot \mathbf{R}$ $\mathbf{T} = [R]_1 \cdots R$ is $\cdots R$ N ^T. transfer between a great influence on the $N-1$ contingency analysis result, such as

the capacity of main transformers and the capacity of ite-lines.

It is an important work in distribution system management to

accurately locate the we the capacity of main transformers and the capacity of tie-lines.

It is an important work in distribution system management to exactling the saccurately locate the weak links and then take targeted and T_i after transfer It is an important work in distribution system management to

and T_i after transferring

improvement measures. In this paper, the influence of the

improvement measures. In this paper, the influence of the

capacity of on the main transformer, main $TRCM_{ij}=TC^{i}$; j=0,

is $\vec{R}^{\dagger} = \vec{R} - \vec{R} \circ \vec{T} = [R^{i_1} \cdots R^{i_i} \cdots R^{i_N}]^T$.

transfer between

ails, the difference between \vec{R} and

main transformer transfer margin,

the dominant fa Locate the weak links and then take targeted

ent measures. In this paper, the influence of the

main transformers and tie-lines on N-1 contingency

transfer between T_i

frain it are mainly considered.

there is no faul *is* an important work in distribution system management to

ccurately locate the weak links and then take targeted

opprovement measures. In this paper, the influence of the

pacity of main transformers and tie-lines on When there is no fault on the main transformer, main $TRCM_{ij} = TC'_{ij} = 0$, then the

Informer margin matrix is $\vec{R} = \vec{R} - \vec{R} \circ \vec{T} = [R_1 \cdots R_i \cdots R_N]^T$. transfer between T_i and T_j

here mean it transformer T_i fails, transformer margin matrix is $R = R \cdot R \cdot T = [R_1 \cdots R_i \cdots R_N]^T$. Transfer between T_i and T_j . If *T*
 *V*hen main transformer T_i fails, the difference between R' and α capacity of tie-line for inter-static

which mean

$$
MRCM = \begin{bmatrix} R' \\ M \\ R' \\ N' \\ R' \\ R' \\ R' \\ R' \end{bmatrix} - TC' \odot \begin{bmatrix} -1 & L & MRCM_{11} & L & MRCM_{1N} \\ -M & 0 & M & 0 & M \\ \hline M & 0 & M & 0 & M \\ \hline M & 0 & M & 0 & M \\ \hline M & 0 & M & 0 & M \\ \hline M & 0 & M & 0 & M \\ \hline M & 0 & M & 0 & M \\ \hline M & 0 & M & 0 & M \\ \hline M & 0 & M & 0 & M \\ \hline M & 0 & M & 0 & M \\ \end{bmatrix} (18) \qquad \text{The flow chart}
$$

When main transformer T_{*i*} fails, the difference between **R**² and
 ω capacity of tie-line for inter-statio

which means the left capacity of other main transformer transfer margin, the dominant factor limiting the
 which means the left capacity of other main transformers after

transferring load. Considering all cases of main transformer than the weak link of the N-1 conti

failure, main transformer transfer margin matrix is:
 $\text{M$ **EVALUATE:** The number of the main transferring the load, so the capacity of the main transferse and the all the main transfer and $MRCM_{1,i}$ $\begin{bmatrix} \mathbf{R}^T \\ \mathbf{N} \\ \math$ When T*ⁱ* fails, if *MRCMi*,*j*[≠]0, then T*^j* has residual capacity **EXECUTE:**
 ARCAL AFTER AFTER ARCAL AFTER ANCAL AFTER AFTER ALSORITI
 ARCAL AFTER \begin{bmatrix} 18 \\ 18 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ MRCM = $\begin{bmatrix} M \\ R' \\ M' \end{bmatrix} - TC' \theta \begin{bmatrix} M_{RCM_{i,j}} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ \end{bmatrix}$ (18) The flow chart of method proposed in this $\begin{bmatrix} N_{RCM_{i,j}}$ **EXECUTE:** $\begin{vmatrix} \mathbf{M}\mathbf{R}\mathbf{C}\mathbf{M} = \begin{vmatrix} \mathbf{R}^* & -\mathbf{R}^* & -\mathbf{R$

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capacity of the main transformer T_j is the dominant factor
limiting the increment of the MTC and the weak link of the *N* It is not been fully edited. Content may change prior to final publication.

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capacity of the main transformer T_j is the dominant factor

limiting the increment of the MTC and the weak link of

inter-station transfer (including type-B and type-C transfer) as not been fully edited. Content may change prior to final publication. 5
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capacity of the main transformer T_j is the dominant factor
limiting the increment of the MTC and the weak link of the *N* not been fully edited. Content may change prior to final publication.

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pacity of the main transformer T_j is the dominant factor

intingency analysis of the main transformer T_i .

Capacity of tie-lin as not been fully edited. Content may change prior to final publication.

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capacity of the main transformer T_j is the dominant factor

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capacity of the main transformer T_j is the dominal
limiting the increment of the MTC and the weak link of
contingency analys Figure 1.1 is the dominant faith

117C and the weak link of the

in transformer T_i .

if ails, the tie-line capacity

12 ig type-B and type-C trans
 $\sum_{(m-1)\sum}^{N_{m_{\Sigma}}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j}$

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the main transformer T_i is the dominant factor

norement of the MTC and the weak link of the *N*-1

analysis of the main transformer T_i.
 of tie-line

$$
TCM'_{i,j} = TCM_{i,j} + \sum_{k=N_{(m-1)\Sigma}+1, k \neq i}^{N_{m\Sigma}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j} \tag{19}
$$

(ie-line transfer margin matrix is:
 $T_{\text{RCM}} =$ **i** is the mass of the mass of the mass of main transformer \overline{T}_j is the dominant factor
 i g the increment of the MTC and the weak link of the *N*-1

ency analysis of the main transformer \overline{T}_i .
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main transformer T_j is the dominant factor

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llysis of the main transformer T_i .
 tie-lines

transformer T_i fai and Energy Systems
pacity of the main transformer T_j is the dominant factor
inting the increment of the MTC and the weak link of the *N*-1
intingency analysis of the main transformer T_i .
Capacity of tie-lines
When mai capacity of the main transformer T_j is the dominant factor
limiting the increment of the MTC and the weak link of the *N*-1
contingency analysis of the main transformer T_i .
B. Capacity of tie-lines
When main transfo *i*, the dominant factor

the weak link of the *N*-1

prmer T_i .
 \neq tie-line capacity for
 $\iint_{i,k} \cdot b_{k,j} \cdot TCM_{k,j}$ (19)
 ∞

substation where T_i is
 $\iint_{i,j}$ and TC^i_{ij} is tie-line
 $\iint_{i,j}$ tie-line capaci Expectively of the number and showner T_i is the contingency analysis of the main transformer T_i .
 B. Capacity of tie-lines

When main transformer T_i fails, the tie-line capacity for

inter-station transfer (includ contingency analysis of the main transformer T_i .
B. Capacity of tie-lines
When main transformer T_i fails, the tie-line capacity for
inter-station transfer (including type-B and type-C transfer)
between T_i and T_j i *B. Capacity of tie-lines*

When main transformer T_i fails, the tie-line capacity for

inter-station transfer (including type-B and type-C transfer)

between T_i and T_j is:
 $TCM'_{i,j} = TCM_{i,j} + \sum_{k=N_{(m-1)2}+1, k\neq i}^{N_{m$ B. Capacity of tie-lines

When main transformer T_i fails, the tie-line capacity for

inter-station transfer (including type-B and type-C transfer)

between T_i and T_j is:
 $TCM'_{i,j} = TCM_{i,j} + \sum_{k=N_{(m-i)\Sigma}+1, k\neq i}^{N_{m\Sigma}}$ *^N ^N N N ^N N* $\begin{bmatrix} \text{margin, which means the left tie-line capacity for} \\ \text{ation transfer between } T_i \text{ and } T_j \text{ after transferring when} \\ \text{in. Considering all cases of main transformer failure,} \\ \text{transfer margin matrix is:} \end{bmatrix}$
 $\begin{bmatrix} \text{RCM}_{M,N1} & \text{RCM}_{M,N1+1} & \text{RCM}_{M,N1+N2} \\ \text{N} & \text{N} & \text{N} \\ \text{$ man and the contract of the contract of the main transformer T_i fails, the tie-line capacity for

in transfer (including type-B and type-C transfer)

i and T_j is:
 $M'_{i,j} = TCM_{i,j} + \sum_{k=N_{(m-1)2}+1, k\neq i}^{N_{m_2}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j}$ (19)
 m is the serial number Example 17 and T_i and type-B and type-C transfer)

en T_i and T_j is:
 $TCM'_{i,j} = TCM_{i,j} + \sum_{k=N_{(m-1)2}+1,k\neq i}^{N_{m_2}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j}$ (19)

(19), *m* is the serial number of the substation where T_i is

(19), *m* if and T_j is:
 $M'_{i,j} = TCM_{i,j} + \sum_{k=N_{(m-1)E}+1, k\neq i}^{N_{mE}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j}$ (19)
 m is the serial number of the substation where T_i is

the difference between $TCM_{i,j}$ and $TC'_{i,j}$ is tie-line

aargin, which mea EVALUATION T_i and T_j is:
 $(M'_{i,j} = TCM_{i,j} + \sum_{k=N_{(m-1)2}+1, k\neq i}^{N_{m\Sigma}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j}$ (19)
 m is the serial number of the substation where T_i is

The difference between $TCM_{i,j}$ and $TC'_{i,j}$ is tie-line

mar $\begin{array}{lllllllllllll} TCM_{i,j} = TCM_{i,j} + \sum_{k=N_{(m+1)\Sigma}+1, k\neq i}^{N_{m\Sigma}} a_{i,k} \cdot b_{k,j} \cdot TCM_{k,j} & (19) \\ & & (19),\ m \text{ is the serial number of the substitution where } T_i \text{ is} \\ & & \text{ied. The difference between } TCM_{i,j} \text{ and } TC_{i,j} \text{ is tie-line} \\ & & \text{fer margin, which means the left tie-line capacity for -station transfer between } T_i \text{ and } T_j \text{ after transferring when} \\ & & \text{dis. Considering all cases of main transformer failure,} \\ & & \text{in transfer margin matrix is:} \\ & & & \text{in$ FCM_{k,j} (19)

on where T_i is
 C'_{ij} is tie-line

i capacity for

sferring when

ormer failure,
 L L *TRCM_N*, M
 M O M
 L L *TRCM_N*, M
 M O M
 M O M
 L *TRCM_{N+N,}* M

 $i \cdots R[N]$ ^T. transfer between T_i When main transformer T_i fails, the difference between \vec{R} and capacity of tie-line for inter-station transfer between T_i and T_j is *N* in (20), the *i*-th row *j*-th column
contingency analysis result, such as
mers and the capacity of tie-lines.
TRCM_{ity} TRCM $T_RCM_{ij} = TCM$, and
this hand then take targeted
this paper, the influence of the when T_i **Example 11** this paper, the influence of the When T_i fails, if *TRCM*
formers and tie-lines on *N*-1 contingency transfer between T_i and
transformers transferring load, so the can
transfer between T_i and the main t Relink is the part of the distribution network that has

In (20), the *i*-th row *j*-th column element on the *N*-1 contingency analysis result, such as

TRCM_{ij}, TRCM_{ij}-TCM⁻i_i-TCM⁻i_i-TC iii, and TRCM_{ij}-TCM⁻ r of main transformers and the capacity of tie-lines.

ICAM_{IA} TRCM_{IA}⁻ FIC is and IRCM_{IA} TROMATION system management to residual capacity of the line for inter-station transformation vor the distribution system man TRCM_{NNN31} L TRCM_{NNN31} TRCM_{NNN31} L TRCM_{NNN31} L TRCM_{NNN31} L TRCM_{NNN41} L TRCM_{NNN41} L TRCM_{NNN41} L TRCM_{NNN41} L TRCM_{NN41} L TRCM_{NN41} L TRCM_{NN41} L TRCM_{NN41} L TRCM_{NN41} L (20)

In (20), the *i*-th row *j* TRCM_{SEN} L. TRCM_{SENS} TRCM_{SENS} L. TRCM_{SENS} (20)

In (20), the *i*-th row *j* $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$ TRCM_{NAN} 1 TRCM_{NANE} $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

In (20), the *i*-th row *j*-th column element of **TRCM** is

TRCM_{ij}, $TRCM_{i,j} = TCM^{i}$ is *TRCMi*,*j*=*TC*'*i*,*j*=0, then there is no tie-line for inter-station In (20), the *i*-th row *j*-th column element of **TRCM** is

TRCM_{*i*}, *TRCM*_{*i*}^{*-TCM*_{*i*}^{*-TC'*}*i*_{*i*}, and *TRCM*_{*i*}^{*i*} represents the residual capacity of tie-line for inter-station transfer between T_{*i*}} In (20), the *i*-th row *j*-th column element of **TRCM** is

TRCM_{ij}, TRCM_{ij}-TCM'_{ij}-TC'_{ij}, and *TRCM*_{ij} represents the

residual capacity of tie-line for inter-station transfer between T_i

and T_j after transfe In (20), the *i*-th row *j*-th column element of **TRCM** is
 $TRCM_{ij}$, $TRCM_{ij}-TCM_{ij}-TC'_{ij}$, and $TRCM_{ij}$ represents the

residual capacity of tie-line for inter-station transfer between T_i

and T_j after transferring when TRCM_{ij}, TRCM_{ij}=TCM'_{ij}-TC'_{ij}, and TRCM_{ij} represents the
residual capacity of tie-line for inter-station transfer between T_i
and T_i after transferring when T_i fails.
When T_i fails, if TRCM_{ij} \neq 0, then residual capacity of tie-line for inter-station transfer between T_i
and T_j after transferring when T_i fails.
When T_i fails, if $TRCM_{ij} \neq 0$, then tie-line for inter-station
transfer between T_i and T_j has resi mater between I_i and I_j has restaual capacity atter
inferring load, so the capacity of the tie-line for inter-station
infer between T_i and T_j is not the weak link in the *N*-1
intingency analysis of the main trans transferring load, so the capacity of the tie-line for inter-station
transfer between T_i and T_j is not the weak link in the N-1
contingency analysis of the main transformer T_i . If
 $TRCM_{ij}=TC'_{ij}=0$, then there is no ti

*MRCM*_{*i*,1} L –1 L *MRCM*_{*i*,N} (18) The HOW chart of the N-1 conting

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Fig. 3. Distribution network of the main transfer margin matrix and tie-line

Tag. 2. Flow chart of *N*-1 contingency parallel analysis

The specific execution process of each step of the algorithm

is as follows:

a) Para **Example 10** \bullet Calculate the main transformer transfer margin matrix and tie-line

Fragge 2. Flow chart of *N*-1 contingency parallel analysis

is as follows:

The specific execution process of each step of the algorit Fig. 2. Flow chart of N-1 contingency parallel analysis

is as follows:

an Substation process of each step of the algorithm

and proposed in the parameters include connection

relationship, main transformer capacity, tie The specific execution process of each step of the algorithm

is as follows:

a) Parameters input: the parameters include connection

relationship, main transformer capacity, tie-line capacity and

load rate.

b) Establis as follows:

a) Parameters input: the parameters include connection

ad rate.

diatete.

b) Establishment of matrices: establish main transformer

b) Establishment of matrices: establish main transformer

cidence matrix a) Parameters input: the parameters include connection

relationship, main transformer capacity, tie-line capacity and

by Establishment of matrices: establish main transformer

incidence matrix *L*, three types transfer e) Establishment of matrices: establish main transformer

idence matrix *L*, three types transfer contact matrix *A*, *B*, *C*,

in transformer capacity matrix *R* and tie-line capacity matrix
 CM according to the actua b) Establishment of matrices: establish main transformer

incidence matrix *L*, three types transfer contact matrix *A*, *B*, *C*, T₄

main transformer capacity matrix *R* and tie-line capacity matrix

then calculate th incidence matrix *L*, three types transfer contact matrix *A*, *B*, *C*,

main transformer capacity matrix *R* and tie-line capacity matrix
 TCM according to the actual distribution network structure, and

then calculate

transferred.

main transformer capacity matrix *R* and tie-line capacity matrix
 TCM according to the actual distribution network structure, and

then calculate three types transfer matrix ATM , BTM , CTM , CTM , CTM , CTM , CTM
 then calculate three types transfer matrix *ATM*, *BTM*, *CTM*.

c) Calculate the MTC of the system: use the method

proposed in this paper to calculate the MTC through the

transfer matrices and the capacity matrices.

d c) Calculate the MTC of the system: use the method

proposed in this paper to calculate the MTC through the

transfer matrices and the capacity matrices.

d) Obtain result: N-1 contingency analysis result can be

transfer proposed in this paper to calculate the MTC through the

transfer matrices and the capacity matrices.

d) Obtain result: N-1 contingency analysis result can be

transferred.

transferred.

transferred.

e) Find weak links transfer matrices and the capacity matrices.

d) Obtain result: N-1 contingency analysis result can be

obtained by comparing the MTC and the load that needs to be

transformer d.

e) Find weak links: the weak links of Nd) Obtain result: *N*-1 contingency analysis result can be

obtained by comparing the MTC and the load that needs to be

transferred.

c e) Find weak links: the weak links of *N*-1 contingency

analysis can be found accor obtained by comparing the MTC and the load that needs to be

transferred.

the veak links: the weak links of $N-1$ contingency
 $\frac{1}{25}$.

analysis can be found according to the calculation of the main

transformer tran transferred.

e) Find weak links: the weak links of *N*-1 contingency

analysis can be found according to the calculation of the main

transformer transfer margin matrix *IRCM* and tie-line transfer

margin matrix *IRCM*. e) Find weak links: the weak links of N -1 contingency

analysis can be found according to the calculation of the main

transformer transform matrix *IRCM* and the die-line transfer

margin matrix *IRCM* and the impr analysis can be found according to the calculation of
transformer transfer margin matrix **MRCM** and tie-lin-
margin matrix **TRCM**. In terms of the complexity of N-1 contingency
method, the method in this paper needs to ca mplexity of *N*-1 contingency analysis

in this paper needs to carry out algebra

in operations of matrices several times,
 M needs to be judged, so the complexity

thod in [12] needs to carry out double

intra-station *A.* Case verification

In order to find this paper needs to can

operations and Boolean operations of matrices

and every element in *RM* needs to be judged, so

is O[n]. While the method in [12] needs to ca

cycle calcu In the method in the periodic of the interperations and Boolean operations of matrices several times,

O[n]. While the method in [12] needs to team complexity

O[n]. While the method in [12] needs to carry out double

com Expense to the contain of matrix contained the method in Fig. 3. In this example, in Toke I and every element in **RM** needs to be judged, so the complexity comparing the method in this cycle calculation of intra-station t

substations are the mean of the substantial transformers and the lines of the meaning the method in [12] needs to carry out double
cycle calculation of intra-station transfer and inter-station the *N*-1 verification resul Example the comparing the method in the N-1 contingency

as shown in the Section of intra-station transfer and inter-station

transfer, so the complexity is O[n²]. Therefore, the algorithm in

this paper has a relativel Fransfer, so the complexity is O[n²]. Therefore, the algorithm in the N-1 verification results of this paper has a relatively prominent efficiency advantage, which not only guarantees the correctness, but also improves this paper has a relatively prominent efficiency advantage,
this paper has a relatively prominent efficiency advantage,
which not only guarantees the correctness, but also improves
the calculation speed.
M. CASE STUDY
A. Example the calculation speed.

Which not only guarantees the correctness, but also improves

which not only guarantees the correctness, but also improves
 $\frac{1}{2}$ contingency analysis re

A. Case verification

In order Example the distribution speed.

The calculation speed.

VI. CASE STUDY

Textal of all main transform

as to avoid the repeatability

In order to fac **Example 18** and stablishing the contact and the matrix result of all main transformers are to facilitate the comparison of *N*-1 contingency are substations and 6 main transformers is adopted as an example, $\frac{10 \text{ times of the original$

| Substation | Main transformer | Voltage class | Capacity/MVA |
|---------------|---|---------------|--------------------------|
| | T_1 | 35kV/10kV | 20.0 |
| S_1 | T ₂ | 35kV/10kV | 20.0 |
| | T ₃ | 35kV/10kV | 20.0 |
| S_2 | T ₄ | 35kV/10kV | 20.0 |
| | T ₅ | 110kV/10kV | 31.5 |
| S_3 | T ₆ | 110kV/10kV | 31.5 |
| | TABLE II DATA OF TIE-LINES | | |
| Tie-line | Tie-line capacity/MVA | Tie-line | Tie-line capacity/MVA |
| $\frac{1}{2}$ | 20.0 | $\frac{1}{2}$ | 30 |

| | | | TABLE II | | | |
|--|--------------------------|------------------------------|--------------------------------------|--|---------------|-----------------|
| | | DATA OF TIE-LINES | | | | |
| Tie-line | Tie-line capacity/MVA | | Tie-line Tie-line capacity/MVA | | | |
| l_{1-2} | | 20.0 | l_{3-6} | | 3.0 | |
| l_{2-3} | | 8.0 | l_{4-5} | | 5.0 | |
| $l_{2.5}$ | | 3.0 | l_{4-6} | | 5.0 | |
| l_{3-4} | | 20.0 | $\frac{1}{5}$ -6 | | 31.5 | |
| $13 - 5$ | | 5.0 | | | | |
| | | | | | | |
| | | | TABLE III | | | |
| | | COMPARISON OF RESULTS | | | | |
| Load rate | | method | | | Pass the N-1 | Calculation |
| $T = [T_1, T_2, T_3, T_4, T_5, T_6]/\%$ | | | | | verification? | time |
| $T=[50,50,75,75,62.7,62.7]$ | | This paper | | | Yes | 6 _{ms} |
| | | | Ref. [12] | | Yes | |
| Comparing the method in this paper with the method in $[12]$, e $N-1$ verification results of the two methods are consistent, dicating the correctness of the proposed method. In [12], the umeration method is applied and it requires to calculate the 1. contingency englysis result and by and In this nancy by | | | | | | |

*h*₂ 20.0 *h*₄₅ 3.0 *h*₄₅ 5.0 *h*₅₅ 5.0 *h*₄₅ 5.0 *h*₄₅ 5.0 *h*₅₆ 5.0 **TABLE III COMPARISON OF RESULTS COMPARISON OF RESULTS COMP** *indignals* $\frac{1}{2}$
 is $\frac{3}{2}$
 is $\frac{5}{4}$
 is Entrino method is applied and it requires to calculate the M-1 contraction?

Contraction method $\frac{T=[T_1,T_2,T_3,T_4,T_5,T_6]^{\psi_6}}{T=[50,50,75,75,62.7,62.7]}$ This paper $\frac{1}{\pi}$ res 6ms

Comparing the method in this paper wit *N*-1 contracts and the matrix operation is extended the method in the system of the method $\frac{T=[T_1,T_2,T_3,T_4,T_5,T_6]/\%}{T=[50,50,75,75,62.7,62.7]}$ This paper $\frac{1}{\sqrt{2}}$ res $\frac{1}{\sqrt{2}}$ fms $\frac{1}{\sqrt{2}}$ res $\frac{1}{\sqrt{2}}$ f TABLE III

COMPARISON OF RESULTS

T=[T₁,T₂,T₃,T₅,T₄,T₅,T₆]⁹⁶ method

T=[50,50,75,75,62.7,62.7] This paper

Test. [12] Yes 6ms

Comparing the method in this paper with the method in [12],

the *N*-1 verific TABLE III

Load rate

T=[T₁,T₂,T₃,T₄,T₅,T₆]^{9%} method verification? Calculation

T=[50,50,75,75,62.7,62.7] This paper

Tes Gms

Terminon and the method in this paper with the method in [12],

the *N*-1 verific Load rate

Television of RESULTS

Television of Results

Television? This paper

Television? This paper

Television? This paper

Television? This paper

Television of the Comparing the method in this paper with the method $T=[T_1, T_2, T_3, T_4, T_5, T_6]$ ⁹⁶ method rass un ¹ verification?

T=[5.0,50,75,75,62.7,62.7] This paper

T=[50,50,75,75,62.7,62.7] This paper

Comparing the method in this paper with the method in [12],

the *N*-1 verifi T=[50,50,75,75,62.7] This paper
T=[50,50,75,75,62.7] Ref. [12] Yes 12ms
Comparing the method in this paper with the method in [1]
the N-1 verification results of the two methods are consiste
indicating the correctness of IF $\left[\frac{1}{12}, \frac{1}{12}\right]$ $\left[\frac{1}{12}\right]$ $\left[\frac{1}{12}\right]$ $\left[\frac{1}{12}\right]$ $\left[\frac{1}{12}\right]$ $\left[\frac{1}{12}\right]$, $\left[\frac{1$ Comparing the method in this paper with the method in [12], the N -1 verification results of the two methods are consistent, indicating the correctness of the proposed method. In [12], the enumeration method is applied a Comparing the method in this paper with the method in [12], the $N-1$ verification results of the two methods are consistent, indicating the correctness of the proposed method. In [12], the enumeration method is applied a the *N*-1 verification results of the two methods are consistent,
indicating the correctness of the proposed method. In [12], the
enumeration method is applied and it requires to calculate the
N-1 contingency analysis re indicating the correctness of the proposed method. In [12], the enumeration method is applied and it requires to calculate the $N-1$ contingency analysis result one by one. In this paper, by establishing the contact matri enumeration method is applied and it requires to calce *N*-1 contingency analysis result one by one. In this establishing the contact matrices and the capacity mair carrying out the matrix operation, the *N*-1 contingency

B. Analysis of weak links and the optic. In this paper, establishing the contact matrices and the capacity matrices a carrying out the matrix operation, the $N-1$ contingency analy result of all main transformers can be Experimently the matrix operation, the *N*-1 contingency analysis sult of all main transformers can be obtained at one time, so to avoid the repeatability verification process in the process enumerating each fault.
If the

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Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power 7

| | DATA OF MAIN TRANSFORMERS | | | | | | | |
|----------------|---------------------------|--------------------------|--------------------------|--------------------------|------------|--|--|--|
| | Load/M VA | Capacity/M VA | Voltage class | Main transformer | Substation | | | |
| $MRCM =$ | 19.7 | 31.5 | 110kV/10kV | T_1 | | | | |
| | 24.2 | 31.5 | 110kV/10kV | T ₂ | S_1 | | | |
| | 19.5 | 31.5 | 35kV/10kV | T ₃ | | | | |
| | 20.1 | 31.5 | 35kV/10kV | T ₄ | S_2 | | | |
| | 26.2 | 40 | 35kV/10kV | T_5 | S_3 | | | |
| | 24.3 | 40 | 35kV/10kV | T ₆ | | | | |
| | 16.3 | 31.5 | 110kV/10kV | T ₇ | S_4 | | | |
| As can be | 16.3 | 31.5 | 110kV/10kV | T_8 | | | | |
| | 21.3 | 31.5 | 110kV/10kV | T ₉ | | | | |
| the transfer i | 19.7 | 31.5 | 110kV/10kV | T_{10} | S_5 | | | |
| transmission | | | | | | | | |
| links in the | | | TABLE V | | | | | |
| points out th | | | DATA OF TIE-LINES | | | | | |
| but it didn't | | Tie-line capacity/MVA | Tie-line | Tie-line capacity/MVA | Tie-line | | | |
| result in this | | 883 | (35, 36) | 2.06 | (16.40) | | | |

(16,40) 2.06 (35,36) 8.83

(33,39) 2.06 (59,60) 7.64 Similarly, when the main

(41,42) 2.06 (4,5) 8.83 margin of the main transfer

(10,31) 4.43 (19,58) 8.83 margin of the main transfer

(22,23) 7.64 (17,18) 11.3 TABLE VI (3.3,39) 2.06 (39,60) 7.64 (1.42) 2.06 (3.9,8) 5.63

(10,31) 4.43 (19,58) 8.83 margin of the main transform

(10,31) 4.43 (19,58) 8.83 Therefore, the capacity of

(22,23) 7.64 (17,18) 11.3 contingency analysis of T₃.

T (10,31) 4.43 (19,58) 8.83 Harger of the than it

(22,23) 7.64 (17,18) 8.83 Therefore, the capacity contingency analysis of
 $\frac{19.7}{10.7}$ COMPARISON OF RESULTS

The MTC of each main transformer calculated by the method
 (22,23) 7.64 (17,18) 11.3 FIECLOUC, and contingency analysis of T₃

method Pass the *N*-1 Calculation

This paper Trees Sms Result 15 continues of T₃

The MTC of each main transformer calculated by the method

in thi TABLE VI

COMPARISON OF RESULTS

This paper

The MTC of each main transformer calculated by the method

in this paper and the N-1 contingency analysis result is shown

in Table VII. It can be seen from Table VII that the 1.92MW. Yes $\frac{8 \text{ ms}}{15 \text{ ms}}$

The Tes $\frac{15 \text{ ms}}{15 \text{ ms}}$

Transformer calculated by the method

contingency analysis result is shown

teen from Table VII that the main

s~T₁₀ can pass the *N*-1 verification,

ner T₃ and Example 15 and Tau Termin Tansformer calculated by the method
 N-1 contingency analysis result is shown

t can be seen from Table VII that the main
 \sim T₂ and T₅ \sim T₁₀ can pass the *N*-1 verification,

transform

the transfer margin of the main transformer T_2 and T_6 are 0 after transmission. Therefore, the capacity of T_2 and T_6 are weak but it didn't consider inner-station main transformer. So the result in this paper is correct and more accurate. MRCM = $\frac{11.8}{11.8}$ (0) $\frac{12}{12}$ $\frac{7.8}{28}$ -1 (0) $\frac{15.2}{15.2}$ $\frac{15.2}{256}$ $\frac{297}{279}$
 $\frac{100}{27.3}$ $\frac{12}{12}$ $\frac{11.4}{14}$ $\frac{13.8}{15.7}$ -1 (0) $\frac{10.2}{11.8}$
 $\frac{11.8}{11.8}$ (0) $\frac{12}{12}$ \frac 11.8 (0) 12 7.28 (0) -1 15.2 15.2 2.56 2.97

(0) 7.3 12 11.4 13.8 15.7 (1) 10.2 11.8

11.8 (0) 12 11.4 13.8 (0) 15.2 15.2 (1)

11.8 (0) 12 11.4 13.8 (0) 15.2 15.2 (0) -1

11.8 (0) 12 11.4 13.8 (0) 15.2 15.2 (0) -1

21)

A $\begin{bmatrix}\n0 & 7.3 & 12 & 11.4 & 13.8 & 15.7 & -1 & 00 & 10.2 & 11.8 \\
\hline\n0 & 7.3 & 12 & 11.4 & 13.8 & 0 & 15.2 & 15.2 & -1 & 0\n\end{bmatrix}$ 11.8 (a) $12 & 11.4 & 13.8 & 0 & 15.2 & 15.2 & -1 & 0\n\end{bmatrix}$ (21)

As can be seen from (21), when the main transform **EXECUTE:** $\frac{1}{11.8}$ ($\frac{1}{11.8}$ $\frac{1}{11.8}$ $\frac{1}{11.4}$ $\frac{13.8}{13.8}$ $\frac{1}{11.8}$ $\frac{1}{11.8}$ $\frac{1}{11.4}$ $\frac{13.8}{13.8}$ $\frac{1}{11.8}$ $\frac{1}{11.8}$ $\frac{1}{11.8}$ $\frac{1}{11.4}$ $\frac{13.8}{13.8}$ $\frac{1}{11.8}$ $\frac{1$ The capacity of T₄ is weak link in the *N*-1

Therefore, the capacity of T₄ is a capacity of T₄ is weak link when T₅ fails, t [11.8 (0) 12 11.4 13.8 (0) 15.2 15.2 (0) -1]
(21)
As can be seen from (21), when the main transformer T₅ fails
the transfer margin of the main transformer T₂ and T₆ are 0 after
transmission. Therefore, the capacity

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<i>TRCM*_{5,1} This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may
Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy System This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may channel (ditation information: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy Sy This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may charched Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Ener This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may channel Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energ This article has been accepted for publication in a future issue of this journal, but has Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power
 TRCM_{5,1}=*TRCM_{5,3}*=*TRCM_{5,7}*=*TRCM_{5,8}*=0, is article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content n

ation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy Systems
 CCM This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change Citation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may channel (Situation information: DOI: 10.1775/CSEEJPES.2021.01490, CSEE Journal of Power and Ener This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Contation information: DOI: 10.17775/CSEEJPES.2021.01490, CSEE Journal of Power and Energy Systems
 *TRCM*₅ Finstation information: DOI: 10.1775/CSEEJPES.2021.01490, CSEE Journal of Power and Transformer TRCM_{5,1}=TRCM_{5,3}=TRCM_{5,7}=TRCM_{5,8}=0, there is no tie-line [5] J
for inter-station information: DOI: 10.1775/CSEEJPES.20

The between 15 and 1₁, 1₃, 1₇, 1₈, let alone that the capacity of the between 15 and 1₁, 13, 17, 1₈, let alone the consideration of the paper, weak link when T₅ fails, but it spaces the consideration. So the

N-1 contingency and T₄ is the weak inks. Keterence [22] points out that the capacity of

didn't take type-C transfer into consideration. So the result is the weak link when T₅ fails, but it the system Technology, vol the-line between Is and I4 is the weak link when Is fails, but it space.

Althin take type-C transformer accurate.

Similarly, when the main transformer T₃ fails, the result in The Mang. Study on Fast

Similarly, when t didn't take type-C transfer mto consideration. So the result in

this paper is correct and more accurate.

In Summar, Sundy on Fast

Insultively Summar T₃ fails, the residual

Ign X. F. Zhu, C. C. Zhou, J.

capacity of this paper is correct and more accurate.

Similarly, when the main transformer T₃ fails, the residual [8] X. F. Zhou, J. H. Y.

capacity of the lines for inter-station transmission between T₃ analysis of load transfer Similarly, when the main transformer 1₃ tails, the residual [8] X. F. Zhu, C. Zhou, N. H. Zhu, C. Zhou, N. H. Zhu, C. Zhou, N. H. Zhu, C. Zhou, A. H. Yang, O. Fang et all analysis of the lines for inter-station. Therefo capacity of tie-lines for inter-station transmission between 13
and T₂, T₅ are 0 after transmission. Therefore, the capacity of
these tie-lines are the weak links in the *N*-1 contingency
mandysis of the main transfor and 12, 1's are 0 atter transmission. Therefore, the capacity of

these tie-lines are the weak links in the *N*-1 contingency [9] L. Ma, J. H. Yang, H. Thang, Q. Fang et al.

analysis of the main transformer T₃.

VII. C these tie-lines are the weak links in the *N*-1 contingency [9] L. Ma, 0.1 Yang, C. Farge tal.,

analysis of the main transformer T₃.

MIC CONCLUSION [10] X. M. Yang, H. Zhao, S. R. Gui

In this paper, the analytical ex comparing the MTC is obtained by calculating the comparing the main transformer is obtained the main transformer

the main transformer system based on subsection of MTC MTC MTC MTC MTC (The main transformer system based on VII. CONCLUSION [10] X. M. Yang, H. Zhong, The main transformer incidence matrix is etablished, and according to the different tran VII. CONCLUSION [10] X.M. Y Ying, H. Zhone, S. R. Goil et analytical expression of main transformer system based on subsection load M-1 contingency analysis of distribution network based on imposing incidence matrix is rea In this paper, the analytical expression of main transformer
 Flectrical Engineering and Energy
 N-1 contingency analysis of distribution network based on

incidence matrix is etailed. The main transformer incidence m N-1 contingency analysis of distribution network based on $\frac{1}{2}$ X. Jing, X. B. Li, Z. F. Wur et al.

matrix is established, and according to the different transformer incidence [11] 2 X. Jing, X. B. Li, Z. F. Wur et the *^N*-1 contingency analysis are identified. The result of an matrix is established, and according to the different transfer

ways, the transfer process is divided into three types, and the

contact main-transformer constantit", *Por*

contact matrices are established respectively. paper. The method proposed in this paper are extablished respectively. Considering main [12] J. Xiao, X. X. Gong, Consider inferent and tie-line capacity constraints, capacity λ Networks", Automative MC is obtained by calcula transformer capacity and tie-line capacity constraints, capacity

matrices of main transformers and tie-lines are established, and

the MTC is obtained by calculating the correlation matrices. By

comparing the MTC is obt matrices of main transformers and tie-lines are established, and

the MTC is obtained by calculating the correlation matrices. By

comparing the MTC with the load to transformer is obtained,

comparing the MTC with the lo the MTC is obtained by calculating the correlation matrices. By [13] J. Xiao, X. X. Gong, Q. B. He comparing the MTC with the load to transferming, the N -1 comparing of the main transfermer is obtained, N -1 contingenc comparing the MTC with the load to transferring, the $N-1$
contingency analysis result of the main transformer is obtained,
and the analytical expression of $N-1$ contingency analysis is [14] J. Xiao, G. D. Zhen, G
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contingency analysis result of the main transformer is obtained,

and the analytical expression of *N*-1 contingency analysis is [14] J. Xiao, G. D. Zhen, G. Q. Zu et

realized. Through the analysis of the transfer proces and the analytical expression of *N*-1 contingency analysis is [14] J. Xiao, G. D. Zhen, G

realized. Through the analysis of the transfer process, the Verification by *N*-1 Stransfer margin matrices are calculated and the contingency analysis and line section *N*-1 contingency analysis and line section *N*-1 contingency analysis are identified. The result of an the N-1 contingency analysis are identified. The result of an experiment example can be further explored according to the method proposed in the *N*-1 contingency analysis are determined and
the *N*-1 contingency analysis are identified
example shows the correctness of the meth
paper.
The method proposed in this paper avoi
operation, improves the efficiency of and expresses the result explicitly. In the process of analysis,

the transfer gap and the transfer margin are obtained, and the

weak links are identified, which provide necessary information

for Power Distribution Newo ransfer gap and the transfer margin are obtained, and the

k links are identified, which provide necessary information

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the planning and design of distribution network. In the

ingency analysis and line secti *Society*, vol. 30, no. 12, pp. 357-366, Jun. 2015. (in Chinese)

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