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A fault diagnosis method of power system by quantum algorithm

Zhibo Zhao[1], Shuo Yao[2], Kunpeng Wan[3], Sansan Xiao[4], Zhengying Cai[5*]
[1] College of Electrical Engineering & New Energy, China Three Gorges University, Yichang, China
[2] School of Foreign Language, China Three Gorges University, Yichang, China
[3-5] College of Computer and Information Technology, China Three Gorges University, Yichang, China

Abstract
Because the fault diagnosis of power system is so complex, this paper mainly try to provide a suitable diagnosis method which involved the quantum mechanism of concurrent computation and observation interaction. First, a quantum fault diagnosis method (QFDM) is introduced from conjugation computation and quantum communication in power system. Second, the fault phenomnon is modelled as a kind of quantum data different from classical data. Third, a simple fault diagnosis step based on quantum concurrent computation is listed. Lastly, an example of quantum fault diagnosis is provided, the proposed model can depict the fault in power system not involving any classical information.

Keywords: power system, fault diagnosis, quantum algorithm, quant um fault diagnosis method

1. Introduction
1.1 Related Work
Now the fault diagnosis method of power system wan more and mre attention. Gao, Zhiwei 2015) talked about a survey of fault diagnosis and fault-tolerant techniques-part i: fault diagnosis with model-based and signal-based approaches [1]. Jana, Subhra (2017) set up a novel zone division approach for power system fault detection using ann-based pattern recognition technique [2]. Lai, Zhi-hui (2016) adopted a weak-signal detection technology based on the stochastic resonance of bistable Duffing oscillator and its application in incipient fault diagnosis [3]. Lv, Yong (2016) produced a multivariate empirical mode decomposition and its application to fault diagnosis of rolling bearing [4]. Zhang, Wei (2018) considered A deep convolutional neural network with new training methods for bearing fault diagnosis under noisy environment and different working load [5]. Rai, Akhand (2016) proposed a review on signal processing techniques utilized in the fault diagnosis of rolling element bearings [6].

In the process, novel and intelligent fault diagnosis methods became popular. Lei, Yaguo (2016) indicated An intelligent fault diagnosis method using unsupervised feature learning towards mechanical big data [7]. Chen, Peng (2016) depicted an improved SVM classifier based on double chains quantum genetic algorithm and its application in analogue circuit diagnosis [8].

Among quantum method takes particular role in the faut diagnosis because of its quantum mechanism. Gao, Zehai (2017) put forward a deep quantum inspired neural network with application to aircraft fuel system fault diagnosis [9]. Huang, Hongxing (2015) etched Detection of interferon-gamma for latent tuberculosis diagnosis using an immunosensor based on cds quantum dots coupled to magnetic beads as labels [10]. Zhu, Kai (2016) unveiled the optimal placement of sensors on a concrete arch dam using a quantum genetic algorithm [11]. Yukawa, Hiroshi (2017) studied the vivo fluorescence imaging and the diagnosis of stem cells using quantum dots for regenerative medicine [12]. Here we proposed a fault diagnosis method of power system by quantum algorithm.

1.2 Organization of the Article
Section 2 contains the quantum information in fault diagnosis of power system. In section 3, it introduces the process of quantum fault diagnosis method. In section 4, a simple example is given to depict Quantum Fault Diagnosis Method. Section 5 summarizes the thesis.

2. Quantum Information in Fault Diagnosis of Power System
2.1 Quantum Hilbert Spaces
A Hilbert space, relating to an isolated physical system, is named as the state space of the system. In the article, finite-dimensional as well as countably infinite-dimensional Hilbert spaces will be mainly considered. A finite-dimensional Hilbert space is a complex vector space O, with an inner product. The inner product is a mapping $\langle \cdot \mid \cdot \rangle$: O ×O →$\mathcal{S}$ meeting the properties as follows:

1. $\langle \varphi|\varphi \rangle \geq 0$ with equality if and only if $|\varphi\rangle = 0$;
2. $\langle \varphi|\psi \rangle = \langle \psi|\varphi \rangle^*$;
3. $\langle \varphi|\lambda_1\psi_1 + \lambda_2\psi_2 \rangle = \lambda_1\langle \varphi|\psi_1 \rangle + \lambda_2\langle \varphi|\psi_2 \rangle$,

in which $\mathcal{S}$ represents the set of complex numbers, but for every complex number $\lambda \in \mathcal{S}$, λ^* is the conjugate of λ. In the article, the infinite-dimensional Hilbert space can be simply viewed as a tensor product of a lot of finite-dimensional Hilbert spaces.

Let n ≥ 1. For any $|\varphi\rangle = (\alpha_1, \dots, \alpha_n)^T$, $|\psi\rangle = (\beta_1, \dots, \beta_n)^T \in \mathcal{S}^n$ and $\lambda \in \mathcal{S}$, we define

$$|\psi\rangle + |\varphi\rangle = (\alpha_1 + \beta, \dots, \alpha_n + \beta_n)^T,$$
$$\lambda|\varphi\rangle = (\lambda\alpha_1, \dots, \lambda\alpha_n)^T$$

in which ^{T} represents transpose. Accordingly $\mathcal{S}^n$ is a vector space. For the adjoint $|\varphi\rangle^\dagger$ of $|\varphi\rangle$, $\langle\varphi|$ is often written. Moreover, define $\langle\cdot|\cdot\rangle$ in $\mathcal{S}^n$ as below.

$$\langle\varphi|\psi\rangle = \sum_{i=1}^{n} \alpha_i^* \beta_i$$

($\mathcal{S}^n$, $\langle\cdot|\cdot\rangle$) is an n-dimensional Hilbert space. In fact, for each n-dimensional Hilbert space, it is isometric to Cn. Among others, a qubit, whose state space is $O_2 = \mathcal{S}^2$, is a physical system. Suppose, write $|0\rangle = \begin{pmatrix}1\\0\end{pmatrix}$ and $|1\rangle = \begin{pmatrix}0\\1\end{pmatrix}$, w
hich is equal to one-bit classical values and is called the computational basis, thus, a qubit has state $\alpha|0\rangle + \mathrm{h}|1\rangle$ with d, N $\in\mathcal{S}$ and $|\mathrm{d}|^2 + |\mathrm{h}|^2 = 1$. The following two states are consisted of the Hadamard basis.

$$|+\rangle = \frac{1}{\sqrt{2}}(|1\rangle + |0\rangle),$$
$$|-\rangle = \frac{1}{\sqrt{2}}(|1\rangle + |0\rangle)$$

In O, for any vector $|\psi\rangle$, the length $\|\psi\|$ of which is defined to be $\sqrt{\langle\psi|\psi\rangle}$ .A pure state of a quantum system, in which a vector $|\psi\rangle$ with $\|\psi\| = 1$, is a unit vector in its state space. The basis $\{|i\rangle\}$ with

$$\langle i|j\rangle = \begin{cases}1, & if\ i = j,\\ 0, & otherwise.\end{cases}$$

is an orthonormal basis of a Hilbert space O.
Define the trace of a linear operator *A* on O to be

$$tr(A) = \sum_i \langle i|A|i\rangle$$

A density operator represents a mixed state of a quantum system. A density operator in a Hilbert space O is a linear operator P on it satisfying the conditions as follows:

1. in the sense that $\langle\psi|\mathrm{P}|\psi\rangle \geq 0$ for all $|\psi\rangle$, P is positive;
2. $tr(\mathrm{P}) = 1$.

For density operator, an equivalent concept of which is an ensemble of pure states. An ensemble is a set of the form $\{(\mathcal{U}_i|\psi_i\rangle)\}$. Thus, $\mathcal{U}_i \geq 0$ and $|\psi i\rangle$ is a pure statefor each *i*, and $\sum_i \mathcal{U}_i = 1$.Then

$$\mathrm{P} = \sum_i \mathcal{U}_i|\psi_i\rangle\langle\psi_i|$$

is a density operator. Conversely, an ensemble of pure states can generate each density operator in this way. If *tr* (P) ≤ 1, a positive operator P is called a partial density operator. For the set of partial density operators on O, (O) can be written.

2.2 Quantum Information Operation

A unitary operator on its state space describes the evolution of a closed quantum system. If $U^\dagger U = I_O$, in which $U^\dagger$ is the adjoint of *U* and I_O is the identity operator in O, then a linear operator *U* in O, a Hilbert space, is said to be unitary. As some unitary operator *U* only depends on t_1 and t_2, if P_1 is the state of the system at times t_1 and P_2 is the state of the system at times t_2, then

$$\mathrm{P}_2 = U^\dagger \mathrm{P}_1 U$$

Especially if P_1 is the pure state $|\psi_1\rangle$ and P_2 is the pure state $|\psi_2\rangle$; namely, there is $|\psi_2\rangle = U|\psi_1\rangle$ when $\mathrm{P}_1 = |\psi_1\rangle\langle\psi_1|$ and $\mathrm{P}_2 = |\psi_2\rangle\langle\psi_2|$.
The following two are the often used unitary operators on qubits, the Hadamard transformation

$$H = \frac{1}{\sqrt{2}}\begin{pmatrix}1 & 1\\1 & -1\end{pmatrix}$$

and the Pauli matrices

$$I = \begin{pmatrix}1 & 0\\0 & 1\end{pmatrix}, \quad \mathrm{Q}_\alpha = \begin{pmatrix}0 & 1\\1 & 0\end{pmatrix},$$
$$\mathrm{Q}_\beta = \begin{pmatrix}0 & -i\\i & 0\end{pmatrix}, \quad \mathrm{Q}_\gamma = \begin{pmatrix}1 & 0\\0 & -1\end{pmatrix}$$

A collection $\{M_m\}$ of measurement operators, in which the indexes m are the measurement outcomes, is used to describe a quantum measurement. The measurement operators are required to satisfy the completeness equation

$$\sum_m M_m M_m^\dagger = I_O$$

The probability that measurement result m occurs is given by

$$\mathcal{U}(m) = tr\left(M_m^\dagger \mathrm{P} M_m\right)$$

if the system is in state P.
And after the measurement, the state of the system is

$$\frac{M_m^\dagger \mathrm{P} M_m}{\mathcal{U}(m)}$$

There is $\mathcal{U}(m) = \|M_m|\psi\rangle\|^2$, for the case that P is a pure state $|\psi\rangle$.The post measurement state is

$$\frac{M_m|\psi\rangle}{\sqrt{\mathcal{U}(m)}}$$

3. The Process of Quantum Fault Diagnosis Method

3.1 Diagnosis Step

Give the operational semantics of QFDM by quantum transitions between configurations, and label it by actions. Defined a configuration to be a pair $\langle \mathcal{U}, \mathrm{P} \rangle$, in which $\mathcal{U} \in \mathcal{U}$ is a process, and $\mathrm{P} \in \mathcal{R}(O)$ designates the current state of the environment. By Intuition, P is a valuation of quantum variables. Quantum systems which are represented by different variables may be correlative, for P is permitted to be an entangled state, though instantiations of classical variables can be made independently from each other. Write the set of configurations as *Con*.

Set

$$Act = \{\tau\} \cup Act_{op} \cup Act_{com}$$

for the set of actions, in which $Act_{op} = \{\mathrm{N}[X]\}$, in which X a finite subset of *Var*, and N is a super-operator on $O_X\}$, is the set of quantum operations, and

$$Act_{com} = \{\omega?\alpha, \omega!\alpha : \omega \in Chan \ and \ \alpha \in Var\}$$

including inputs and outputs, is the set of communication actions. Metavariables $\mathrm{d}, \mathrm{h}, \cdots$. will range over the set *Act*. The following notations are needed for actions.

- Use $cn(\mathrm{d})$ to represent the channel name in action d, for each $\mathrm{d} \in Act$; namely, $cn(\omega?\alpha) = cn(\omega!\alpha) = \omega$,and $cn(\tau)$ and $cn(\mathrm{N}[X])$ are not stated.
- For the set of free variables in d, write $fv(\mathrm{d})$; namely, $fv(\omega!\alpha) = \{\alpha\}$, $fv(\mathrm{N}[X]) = X$, $fv(\tau) = fv(\omega?\alpha) = \emptyset$.
- $bv(\mathrm{d})$ is defined to be the bound variable in d; namely, $bv(\omega?\alpha) = \alpha$, and $bv(\tau)$, $bv(\mathrm{N}[X])$,and $bv(\omega!\alpha)$ are not stated.

One more auxiliary concept is needed, in order to put forward the operational semantics of QFDM. For any $X \subseteq Var$, and for any super-operator N on O_X, define the cylindric extension of N on O to be

$$N_X \stackrel{\mathrm{def}}{=} \mathrm{N} \otimes \mathcal{J}_{O_{var-\alpha}} \qquad (2)$$

in which $\mathcal{J}_{Ovar-X}$ is the identity operator on O_{Var-X}. In in following, assume that X and N are repectively a finite subset of *Var* and a super-operator on O_X, no matter when N_X is encountered.

Accordingly, the operational semantics of QFDM, in which the transition relation → is defined by the under rules, is given as a transition system $(Con, \mathfrak{f}, \rightarrow)$.

Tau: $\dfrac{}{\langle \tau.\mathcal{U}, \mathrm{P} \rangle \xrightarrow{\tau} \langle \mathcal{U}, \mathrm{P} \rangle}$

Oper: $\dfrac{}{\langle \mathrm{N}[X].\mathcal{U}, \mathrm{P} \rangle \xrightarrow{\mathrm{N}[X]} \langle \mathcal{U}, \mathrm{N}_X(\mathrm{P}) \rangle}$

Input: $\dfrac{}{\langle \omega?\alpha.\mathcal{U}, \mathrm{P} \rangle \xrightarrow{\omega?\beta} \langle \mathcal{U}\{\beta \backslash \alpha\}, \mathrm{P} \rangle} \quad \beta \notin fv(\omega?\alpha.\mathcal{U})$

Output: $\dfrac{}{\langle \omega!\alpha.\mathcal{U}, \mathrm{P} \rangle \xrightarrow{\omega!\beta} \langle \mathcal{U}, \mathrm{P} \rangle}$

Choice: $\dfrac{\langle \mathcal{U}, \mathrm{P} \rangle \xrightarrow{\mathrm{d}} \langle \mathcal{U}\prime, \mathrm{P}\prime \rangle}{\langle \mathcal{U} + \mathcal{Q}, \mathrm{P} \rangle \xrightarrow{\mathrm{d}} \langle \mathcal{U}\prime, \mathrm{P}\prime \rangle}$

Intl1: $\dfrac{\langle \mathcal{U}, \mathrm{P} \rangle \xrightarrow{\omega?\alpha} \langle \mathcal{U}\prime, \mathrm{P}\prime \rangle}{\langle \mathcal{U} \| \mathcal{Q}, \mathrm{P} \rangle \xrightarrow{\omega?\alpha} \langle \mathcal{U}' \| \mathcal{Q}, \mathrm{P}\prime \rangle} \quad \alpha \notin fv(\mathcal{V})$

Intl2: $\dfrac{\langle \mathcal{U}, \mathrm{P} \rangle \xrightarrow{\mathrm{d}} \langle \mathcal{U}\prime, \mathrm{P}\prime \rangle}{\langle \mathcal{U} \| \mathcal{Q}, \mathrm{P} \rangle \xrightarrow{\mathrm{d}} \langle \mathcal{U}' \| \mathcal{Q}, \mathrm{P}\prime \rangle} \quad \mathrm{d}$ is not an input

Comm: $\dfrac{\langle \mathcal{U}, \mathrm{P} \rangle \xrightarrow{\omega?\alpha} \langle \mathcal{U}\prime, \mathrm{P}\prime \rangle \quad \langle \mathcal{Q}, \mathrm{P} \rangle \xrightarrow{\omega!\alpha} \langle \mathcal{Q}\prime, \mathrm{P} \rangle}{\langle \mathcal{U} \| \mathcal{Q}, \mathrm{P} \rangle \xrightarrow{\tau} \langle \mathcal{U}' \| \mathcal{Q}\prime, \mathrm{P} \rangle}$

Res: $\dfrac{\langle \mathcal{U}, \mathrm{P} \rangle \xrightarrow{\mathrm{d}} \langle \mathcal{U}\prime, \mathrm{P}\prime \rangle}{\langle \mathcal{U} \backslash L, \mathrm{P} \rangle \xrightarrow{\mathrm{d}} \langle \mathcal{U}' \backslash L, \mathrm{P}\prime \rangle} \quad cn(\mathrm{d}) \notin L$

Def: $\dfrac{\langle \mathcal{U}\{\tilde{\beta}/\tilde{\alpha}\}, \mathrm{P} \rangle \xrightarrow{\mathrm{d}} \langle \mathcal{U}\prime, \mathrm{P}\prime \rangle}{\langle A(\tilde{\beta}), \mathrm{P} \rangle \xrightarrow{\mathrm{d}} \langle \mathcal{U}', \mathrm{P}\prime \rangle} \quad A(\tilde{\alpha}) \stackrel{\mathrm{def}}{=} \mathcal{U}$

In the previous table, the symmetric forms of the Choice, Intl1, Intl2, and Comm rules are omitted.

Eq. (2) defined the operator $\mathrm{N}_{X(\cdot)}$ in the Oper rule. Through channel *c*, the x-system is sent out in the output transition $\langle \omega!\alpha.\mathcal{U}, \mathrm{P} \rangle \xrightarrow{\omega!\alpha} \langle \mathcal{U}, \mathrm{P} \rangle$. The current state of the x-system is in P. This should be noticed. However, it is not necessary for P to be a separable state. Besides, for some $\beta \in Var - \{\alpha\}$, it is possible that the x-system is tangled with the *y*-system. Furthermore, after the action $\omega!\alpha$, the entanglement between the *x*-system and the *y*-systems ($\beta \notin Var - \{\alpha\}$) is saved. The input transition $\langle \omega?\alpha.\mathcal{U}, \mathrm{P} \rangle \xrightarrow{\omega?\beta} \langle \mathcal{U}\{\beta/\alpha\}, \mathrm{P} \rangle$ implies that the *y*-system is obtained from channel *c* and put into the (free) occurrences of *x* in $\mathcal{U}$. (Over one free occurrence of a single variable α may be in, for it is not required that $fv(\mathcal{U}) \cap fv(\mathcal{V}) = \emptyset$ in sun $\mathcal{U} + \mathcal{V}$.) In $\omega?\alpha$. $\mathcal{U}$ the variable α is bound, and it does not stand for particularly the *x*-system. This is what should be noted. In the contrary, it is merely a reference to the place, in which the received system will go. Hence, $\omega?\alpha$. $\mathcal{U}$ can operate action $\omega?\beta$ with $\beta \neq \alpha$. For the input transition, the side condition $\beta \notin fv(\omega?\alpha.\mathcal{U})$ is clearly to avoid variable name conflict. And $\mathcal{U}\{\beta/\alpha\}$ is also made to be well defined. Both the input and output actions, the state of the environment is not changed during operating. In a communication which is described by the Comm rule, passing quantum systems happens. However, it is realized in a "call-by-name" scheme, and the state of the environment is not changed.

It is required that $fv(\mathcal{U}') \cap fv(\mathcal{Q}') = \emptyset$ to assure that the Comm rule is logical. Nevertheless, this condition needs not to be imposed into the Comm rule, for it is a result of the other rules.

3.2 Diagnosis Rule

The concept of strong bisimulation on configurations is first introduced.

If for any $\langle \mathcal{U}, P\rangle$, $\langle \mathcal{V}, Q\rangle \in Con$, $\langle \mathcal{U}, P\rangle C\langle \mathcal{V}, Q\rangle$ implies the following, a symmetric relation $\mathcal{S} \subseteq Con \times Con$ is a strong bisimulation.

(1) No matter when $\langle \mathcal{U}, P\rangle \xrightarrow{d} \langle \mathcal{U}', P'\rangle$ and d is not an input, accordingly, for some $\mathcal{V}'$ and Q', $\langle \mathcal{V}, Q\rangle \xrightarrow{d} \langle \mathcal{V}', Q'\rangle$ and $\langle \mathcal{U}', P'\rangle\, T\langle \mathcal{V}', Q'\rangle$.

(2) No matter when $\langle \mathcal{U}, P\rangle \xrightarrow{\omega?\alpha} \langle \mathcal{U}', P\rangle$ and $\alpha \notin fv()\cup fv(\mathcal{V})$, accordingly, for some $\mathcal{V}'$, $\langle \mathcal{V}, Q\rangle \xrightarrow{c?\alpha} \langle \mathcal{V}', Q\rangle$ and for all $\beta \notin fv(\mathcal{U}')\cup fv(\mathcal{V}') - \{\alpha\}$, $\langle \mathcal{U}'\{\beta/\alpha\}, P\rangle\, T\langle \mathcal{V}'\{\beta/\alpha\}, Q\rangle$

In clause 2, that $\beta \notin fv(\mathcal{U}') \cup fv(\mathcal{V}') - \{\alpha\}$ is required should be noted. If this requirement is not put, then after substitution $\{\beta/\alpha\}$, two precedingly different quantum states may become the same state. The no-cloning theorem of quantum information forbids this.

Next, strong bisimilarity between configurations can be defined in a conventional way.

$\langle \mathcal{U}, P\rangle$ and $\langle \mathcal{V}, Q\rangle$ are strongly bisimilar for any $\langle \mathcal{U}, P\rangle$, $\langle \mathcal{V}, Q\rangle \in Con$. If $\langle \mathcal{U}, P\rangle T\langle \mathcal{V}, Q\rangle$ for some strong bisimulation T, written $\langle \mathcal{U}, P\rangle \sim \langle \mathcal{V}, Q\rangle$,; namely, the greatest strong bisimulation is strong bisimilarity on *Con*.

By comparing two processes in the same environment, strong bisimilarity between processes can be defined.

$\mathcal{U}$ and $\mathcal{V}$ are strongly bisimilar for any quantum processes $\mathcal{U}$, $\mathcal{V} \in \mathcal{P}$, if $\langle \mathcal{U}, P\rangle \sim \langle \mathcal{V}, P\rangle$ for all $P \in \mathcal{D}(O)$, written $\mathcal{U} \sim \mathcal{V}$.

In the following, a recursive characterization of strong bisimilarity configurations will be given here. And in establishing strong bisimilarity between some processes, it is useful.

For any $\langle \mathcal{U}, P\rangle$, $\langle \mathcal{V}, Q\rangle \in Con$, $\langle \mathcal{U}, P\rangle \sim \langle \mathcal{V}, Q\rangle$ *if and only if,*

(1) *no matter when* $\langle \mathcal{U}, P\rangle \xrightarrow{d} \langle \mathcal{U}', P'\rangle$ *and α is not an input, accordingly, for some* $\mathcal{V}'$ *and* Q', $\langle \mathcal{V}, Q\rangle \xrightarrow{d} \langle \mathcal{V}', Q'\rangle$ *and* $\langle \mathcal{U}', P'\rangle \sim \langle \mathcal{V}', Q'\rangle$

(2) *no matter when* $\langle \mathcal{U}, P\rangle \xrightarrow{\omega?\alpha} \langle \mathcal{U}', P\rangle$ *and* $x \notin fv(\mathcal{U})\cup fv(\mathcal{Q})$, *accordingly, for some* $\mathcal{V}'$, $\langle \mathcal{V}, Q\rangle \xrightarrow{\omega?\alpha} \langle \mathcal{V}', Q\rangle$ *and for all* $\beta \notin fv(\mathcal{U}') \cup fv(\mathcal{V}') - \{\alpha\}$, $\langle \mathcal{U}'\{\beta/\alpha\}, P\rangle \sim \langle \mathcal{V}'\{\beta/\alpha\}, Q\rangle$, *and the symmetric forms of 1 and 2.*

4. Example and Analysis

How quantum systems are passed between a unitary transformation or how a measurement is operated will be depicted on some quantum systems in the example by using the language of QFDM. What the most interesting thing is observing how entangled systems perform during calculation and communication.

Suppose

$$\mathcal{U}_1 = \omega?\beta.\mathcal{U}'_1,\ \mathcal{U}_2 = \omega!\alpha.\mathcal{U}'_2$$

and $\mathcal{U} = (\mathcal{U}_1||\mathcal{U}_2)\backslash\omega$, in which $\alpha \notin fv(\mathcal{U}_1)$. Therefore, the only possible transition of $\mathcal{U}$ is

$$\langle \mathcal{U}, P\rangle \xrightarrow{\tau} \langle (\mathcal{U}'_1\{\alpha/\beta\}||\mathcal{U}'_2)\backslash\omega, P\rangle.$$

for any P. Notice that the *x*-system is passed from $\mathcal{U}_2$ to $\mathcal{U}_1$ in this transition, but the state P of the environment is not shifted. P does not include any position information of the quantum systems which is under consideration, so this is reasonable; speak more precisely, for all quantum variables α, P only depicts the state of the α-system in a configuration $\langle \mathcal{V}, P\rangle$. However, there is no subprocess of $\mathcal{V}$ possessing the α-system is shown.

Provided

$$\mathcal{V}_1 = \omega?\beta.H[\beta].\mathcal{V}'_1,\ \mathcal{V} = (\mathcal{V}||\mathcal{U}_2)\backslash\omega,$$

and $P = |0\rangle_\alpha\langle 0|\otimes P'$, in which $P' \in \mathcal{D}(O_{Var-\{\alpha\}})$ and $\alpha \notin fv(\mathcal{V}_1)$, then

$$\langle \mathcal{V}, P\rangle \xrightarrow{\tau} \langle (H[\alpha].\mathcal{V}'_1\{\alpha/\beta\}||\mathcal{U}'_2)\backslash\omega, P\rangle \xrightarrow{H[\alpha]} \langle (\mathcal{V}'_1\{\alpha/\beta\}||\mathcal{U}'_2)\backslash\omega, |+\rangle_\alpha\langle +|\otimes P'\rangle$$

The state of the *x*-system is $|0\rangle$ at the start of the transition. Thus, the α-system is passed from $\mathcal{U}_2$ to $\mathcal{V}_1$, and at $\mathcal{V}_1$ the Hadamard transformation is operated on it. After the transition, the state of the α-system becomes $|+\rangle$.

Assume that

$$\mathcal{W}_1 = \omega?\beta.CNOT[\beta,\gamma].\mathcal{W}'_1$$

and $\mathcal{W} = (\mathcal{W}_1||\mathcal{U}_2)\backslash\omega$

and $Q = |+\rangle_\alpha\langle +|\otimes|0\rangle_\gamma\langle 0|\otimes Q'$,

in which $Q' \in \mathcal{D}(O_{Var-\{\alpha,z\}})$

and $\alpha \notin fv(\mathcal{W}_1)$.

Next

$$\langle \mathcal{W}, Q\rangle \xrightarrow{\tau} \langle (CONT[\alpha,\gamma].\mathcal{W}'_1\{\alpha/\beta\}||\mathcal{U}'_2)\backslash\omega, Q\rangle \xrightarrow{CONT[\alpha\gamma]} \langle (\mathcal{W}'_1\{\alpha/\beta\}||\mathcal{U}'_2)\backslash\omega, |N_{00}\rangle_{\alpha\gamma}\langle h_{00}|\otimes Q'\rangle .$$

The α-system is passed from $\mathcal{U}_2$ to $\mathcal{W}_1$, then the *CNOT* operator is applied to the γ-system and it. Before the transition, the state of the αγ-system is separable. This is worth noting. However, at last, an entanglement between the α-system and the γ-system is created.

Suppose

$$\mathcal{L}_1 = \omega?\beta.CONT[\beta,\gamma].\mathcal{M}_{0,1}[\gamma].\mathcal{L}'_1$$

and $\mathcal{L} = (\mathcal{L}_1||\mathcal{U}_2)\backslash c$, in which $\mathcal{M}_{0,1}$, is given by a single qubit measurement in the computational basis $|0\rangle$, $|1\rangle$, is the operation. Its measurement result is unknown; namely,

$\mathcal{M}_{0,1}(\mathrm{P}) = \mathcal{U}_0 \mathrm{P} \mathcal{U}_0 + \mathcal{U}_1 \mathrm{P} \mathcal{U}_1$ for each $\mathrm{P} \in \mathcal{D}(O_2)$, in which $\mathcal{U}_0 = |0\rangle\langle 0|$ and $\mathcal{U}_1 = |1\rangle\langle 1|$. Next

$$\langle \mathcal{L}, \mathrm{Q}\rangle \xrightarrow{\tau} \langle (CONT[\alpha,\gamma].\mathcal{M}_{0,1}[\gamma].\mathcal{L}'_1\{\alpha/\beta\}||\mathcal{U}'_2)\backslash\omega, \mathrm{Q}\rangle$$
$$\xrightarrow{CONT[\alpha,\gamma]} \langle (\mathcal{M}_{0,1}[\gamma].\mathcal{L}'_1\{\alpha/\beta\}||\mathcal{U}'_2)\backslash\omega, |\mathrm{h}_{00}\rangle_{\alpha\gamma}\langle \mathrm{h}_{00}|\otimes \mathrm{Q}'\rangle$$
$$\xrightarrow{\mathcal{M}_{0,1}[\gamma]} \langle (\mathcal{S}'_1\{\alpha/\beta\}||\mathcal{U}'_2)\backslash\omega, \tfrac{1}{2}|00\rangle_{\alpha\beta}\langle 00| + |11\rangle_\gamma\langle 11|)\otimes \mathrm{Q}'\rangle$$

The measurement in computational basis $|0\rangle$, $|1\rangle$ is operated on the γ–system, in the last transition. It is clearly that the α-system and the γ-system are always in the same quantum state, for they are entangled before the measurement.

Therefore, Alice and Bob may be respectively depicted as processes

$$\mathcal{U} = \omega_1!\alpha.\mathcal{U}',\ \mathcal{V} = \omega_2?\gamma.\mathcal{V}';$$

and the channel is depicted as a nullary process constant scheme $\mathcal{S}$, the defining equation of which is

$$\mathcal{S} \stackrel{\text{def}}{=} \omega_1?\beta.\mathrm{N}[\beta].\omega_2!\beta.\mathcal{S}.$$

Set $\mathcal{L} = (\mathcal{U}||\mathcal{S}||\mathcal{V})\backslash\{\omega_1,\omega_2\}$. Provided that a quantum state P of the α-system expresses the information that Alice is to send, therefore, for any $\mathrm{P}' \in \mathcal{R}(O_{Var-\{x\}})$, there is

$$\langle \mathcal{L}, \mathrm{P}\otimes\mathrm{P}'\rangle \xrightarrow{\tau} \langle (\mathcal{U}'||\mathrm{N}[\alpha].\omega_2!\alpha.\mathcal{S}||\mathcal{V})\backslash\{\omega_1,\omega_2\}, \mathrm{P}\otimes\mathrm{P}'\rangle$$
$$\xrightarrow{\mathrm{N}[\alpha]} \langle (\mathcal{U}'||.\omega_2!\alpha.\mathcal{S}||\mathcal{V})\backslash\{\omega_1,\omega_2\}, \mathrm{N}(\mathrm{P})\otimes\mathrm{P}'\rangle$$
$$\xrightarrow{\tau} \langle (\mathcal{U}'||\mathcal{S}||\mathcal{V}'\{\alpha/\gamma\})\backslash\{\omega_1,\omega_2\}, \mathrm{N}(\mathrm{P})\otimes\mathrm{P}'\rangle.$$

Notice that $fv(\mathcal{S})$ does not include *y*; besides, $\mathcal{S}$ is not a process. So $\mathcal{S}\{\alpha/\beta\} = \mathcal{S}$.

Furthermore, in assumption, a system-environment model of N is given. Suppose N_U, $\mathrm{N}_{\mathcal{U}}$, and N_{trE} be super-operators on $O_\alpha\otimes O_E$, and for all $\mathrm{Q} \in \mathcal{R}(O_\alpha\otimes O_E)$, they are defined respectively in the following: $\mathrm{N}_U(\mathrm{Q}) = U_\mathrm{Q} U^\dagger$, $\mathrm{N}_{\mathcal{U}}(\mathrm{Q}) = \mathcal{U}\mathrm{Q}\mathcal{U}$, and

$$\mathrm{N}_{trE}(\mathrm{Q}) = \textstyle\sum_k \langle e_k|\mathrm{Q}|e_k\rangle \otimes |e_0\rangle\langle e_0|.$$

Define process constant scheme $\mathcal{S}'$ by

$$\mathcal{S}'(E) \stackrel{\text{def}}{=} \omega_1?y.\mathrm{N}_U[\{\beta,E\}].\mathrm{N}_{\mathcal{U}}[\{\beta,E\}].\mathrm{N}_{trE}[\{\beta,E\}].\omega_2!\beta.\mathcal{S}'(E)$$

and set $\mathcal{L}' = (\mathcal{U}||\mathcal{S}'(E)||\mathcal{V})\backslash\{\omega_1,\omega_2\}$. Next, for all $\mathrm{P} \in \mathcal{R}(O_x)$ and $\mathrm{P}'' \in V(O_{Var-\{\alpha,E\}})$,

5. Conclusions

At start, a brief review about fault of diagnosis of power system is made. Then the process of the quantum fault diagnosis method is introduced in power system. The mathematical model for quantum state transformations is built by unitary operators. According the diagnosis process of quantum states, unitary operators are employed to describe the dynamics mechanism of power system fault. For the quantum fault diagnosis method is mainly based on quantum concurrent systems and subsystem interactions between different faults, it seems more suitble to take the proposed systems as an open system which can use super-operators to depict the quantum statetransformations. In future research, further understanding of quantum measurement processes is needed, and QFDM will be extended to integrate classical information.

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