A Review on Quantum Battery

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Introduction

- Energy storing is a need of present time. Quantum Mechanics give us a way to store energy in more efficient way.
- The basic Idea of quantum Battery based on entanglement was introduced in 2013 by Mark Fannes and Robert Alicki[Robert Alicki, 2013] They gave a general Hamiltonian and formilism for the system.

- Later it was identified that Entanglement is not required for the working of Quantum Battery[Hovhannisyan K, 2013]
- The idea of 3 level quantum battery was introduced in 2020.[Yuan-Jin Wang, 2020]

General Framework

Passive State

A state is called passive if $Tr(\rho_0 U^\dagger H U) \geq Tr(\rho_0 H)$ for every unitary operators U acting on H.[Lenard, 1978] That means, we cannot extract any energy if the system is in passive state.

Ergotropy

It is the maximum amount of energy that can be extracted from the
system.[Yuan-Jin Wang, 2020],[Felix C Binder and Goold, 2015]

General Treatment

- Initial state: ρ
- Initial Hamiltonian

$$H = \sum_{j=1}^{d} \epsilon_j |j >< j| \qquad \epsilon_{j+1} = \epsilon_j \tag{1}$$

- The driving field is $V(t)$. $V(t)$ is Hermitian.
- Time evolution of the state is

$$i\hbar\dot{\rho} = [H(t), \rho(t)] \tag{2}$$

where $H(t) = H + V(t)$ [Robert Alicki, 2013]
- $V(t)$ is the charging field(or dischatging)

General Treatment

- The work that can be extracted then

$$W = Tr(\rho H) - Tr(\rho(\tau)H) \tag{3}$$

- τ: time passed

$$\rho(\tau) = U^{\dagger}(\tau)\rho U(\tau) \tag{4}$$

$$U(\tau) = T\exp\left(-i\int_0^{\tau} dt[H + V(t)]\right)$$

Then, the ergotropy:

$$C = \max W = Tr(\rho H) - \min Tr(\rho(\tau)H) \tag{5}$$

[Robert Alicki, 2013]

Charging

Energy of the internal system at a particular time(t) is

$$E(t) = Tr[\rho(t)H(t)]$$

- Lowest state:$\hat{\pi}$;Highest state:$\hat{\omega}$
- $$\hat{\pi} = \sum_i p_i|\epsilon_i >< \epsilon_i| \qquad p_i \geq p_{i+1} \tag{6}$$
  $$\hat{\omega} = \sum_i p_i|\epsilon_i >< \epsilon_i| \qquad p_i \leq p_{i+1} \tag{7}$$
- $\hat{\pi}$ and $\hat{\omega}$ are related via a unitary transformation.[Felix C Binder and Goold, 2015]

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