$$\hat{\mathrm{V}} = -J \cdot \sum_{\langle l,m \rangle} \left(\hat{\mathrm{h}}_l^{\dagger} \hat{\mathrm{h}}_m + \hat{\mathrm{h}}_m^{\dagger} \hat{\mathrm{h}}_l + \hat{\mathrm{d}}_l^{\dagger} \hat{\mathrm{d}}_m + \hat{\mathrm{d}}_m^{\dagger} \hat{\mathrm{d}}_l \right)$$

$$\hat{\mathrm{h}}_m^{\dagger \mathrm{I}}(t) = e^{i \cdot \varepsilon_m \cdot t} \left(1 + \left(e^{i \cdot U \cdot t} - 1 \right) \hat{\mathrm{d}}_m^{\dagger \mathrm{S}} \hat{\mathrm{d}}_m^{\mathrm{S}} \right) \hat{\mathrm{h}}_m^{\dagger \mathrm{S}}$$

$$\hat{\mathrm{h}}_m^{\mathrm{I}}(t) = e^{-i \cdot \varepsilon_m \cdot t} \left(1 + \left(e^{-i \cdot U \cdot t} - 1 \right) \hat{\mathrm{d}}_m^{\dagger \mathrm{S}} \hat{\mathrm{d}}_m^{\mathrm{S}} \right) \hat{\mathrm{h}}_m^{\mathrm{S}}$$

$$\hat{\mathrm{d}}_m^{\dagger \mathrm{I}}(t) = e^{i \cdot \varepsilon_m \cdot t} \left(1 + \left(e^{i \cdot U \cdot t} - 1 \right) \hat{\mathrm{h}}_m^{\dagger \mathrm{S}} \hat{\mathrm{h}}_m^{\mathrm{S}} \right) \hat{\mathrm{d}}_m^{\dagger \mathrm{S}}$$

$$\hat{\mathrm{d}}_m^{\mathrm{I}}(t) = e^{-i \cdot \varepsilon_m \cdot t} \left(1 + \left(e^{-i \cdot U \cdot t} - 1 \right) \hat{\mathrm{h}}_m^{\dagger \mathrm{S}} \hat{\mathrm{h}}_m^{\mathrm{S}} \right) \hat{\mathrm{d}}_m^{\mathrm{S}}$$