The actual energy commitment of this wind farm, yti, is normal distributed with its mean value equal to 1 Kwh/hr. And because of the discontinuity and volatility of the wind resource, the power generator decides to use energy storage device to help achieve decided commit energy flow, xti, per hour, every day.

The energy price, pti, is normal distributed with its mean value equal to $0.055 per hour cross t days. The system total revenue is defined as commit energy flow decision, xti, times its price, pti. The commit energy flow decision xti is composed by yti, the actual winds power commitment to client, Δzti, energy storage level changes, and adding energy flow from winds power to battery, and unmet uncertainty.

There is uncertainty of unmet energy with beta random process and 1% energy loses as heat while crossing each hour, therefore, the profit of this energy system in current period is deducted by two future factors fd (energy loses) and fu (unmet) in the next period, which are quantity yd and yu times prices at *t* day and *i* hour. And, the energy storage level of the system may not exceed battery capacity and lower than zero. The system owner is aiming to find the max reward each period with consideration of these conditions by backward recursion.

Formulation

$$\boldsymbol{V_t}\ (\boldsymbol{R_t}|\boldsymbol{q_t}) = \mathbf{max}\left(\sum_{i=1}^{24} \boldsymbol{rev}(\boldsymbol{x_{t,i}}, \boldsymbol{p_{t,i}}) - \boldsymbol{f^d}\ (\boldsymbol{y^d_{t+1,i}}, \boldsymbol{p_{t,i}}) - \boldsymbol{f^u}\ (\boldsymbol{y^u_{t+1,i}}, \boldsymbol{p_{t,i}})\right) + \boldsymbol{E}(\boldsymbol{V_{t+1}}(\boldsymbol{R_{t+1}})|\boldsymbol{q_{t+1}}|\boldsymbol{Q_t})$$

Subject to

$V_t(R_t) = 0$

Battery Capacity： Rj

qt： beta random process for unmet energy between each period

Qt： filtration from qt

Days： t = 0,…T-1

Hours： i = 1…24

$$x_{t,i} = y^{x}_{t+1,i} + y^{rem}_{t+1,i} + y^{u}_{t+1,i}$$

$$y^{rem}_{t+1,i} = z_{t+1,i-1} - z_{t+1,i} + y^{add}_{t+1,i}$$

$$z_{t+1,1} = R_t \;,\; z_{t+1,i} \geq 0,\; z_{t+1,i} \leq Rj$$

Battery storage level transition per day： $R_{t+1} = z_{t+1,24}$

Power from Wind to Commitment： $y^{x}_{t+1} \sim N(1000, 1)(kwh)$

Commitment Decision Variable： $x_{t,i} \sim kwh$

Wind Power Price per hour： $P_{t,i} \sim N(0.055, 1)$ $(\$/kwh)$

Storage Power to Commitment： $y^{rem}_{t+1} \sim N(900, 1)$ (kwh)

Wind Power to Battery Storage： $y^{add}_{t+1} \sim N(900, \sigma^2)$ (kwh)

Process Unmet Commitment: $y^{u}_{t+1} \sim$ **Random Uniform times 80 with Beta (** α **,** β **)** (kwh)

$f^d\left(y^{d}_{t+1,i}, p_{t,i}\right)$ *and* $f^u\left(y^{u}_{t+1,i}, p_{t,i}\right)$**： energy loses and unmet energy respectively**