

Improvement of operating efficiency of Energy Cooperatives with the use of *crypto-coin mining*. Optimizations models.

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1 Optimal source size

1.1 Introduction

In this document, we will describe the optimization model that was used to generate the results in the *Improvement of operating efficiency of Energy Cooperatives with the use of “crypto-coin mining”* article.

1.2 Variables and parameters

1.2.1 General markings

- \mathbb{R} - set of real numbers,
- \mathbb{R}_+ - set of non-negative real numbers,
- \mathbb{I} - set of integer numbers,
- \mathbb{I}_+ - set of non-negative integer numbers,
- $\mathbb{B} = \{0, 1\}$,
- $card(X)$ - cardinality of set X .

1.2.2 Sets and parameters

- $BigM$ - big real number,
- $\mathbb{H} = \{1, 2, \dots, H\}$ - set of optimization period hours,
- $\mathbb{M} = \{1, 2, \dots, M\}$ - set of optimization period months,
- NC - number of cryptocurrency excavator,
- EC - unit demand of an excavator for electricity,
- $SCh \in \mathbb{M} := (m - 1) \cdot 30 \cdot 24 + 1$ - first hour of charging the substorages,
- $SDis \in \mathbb{M} := (m - 1) \cdot 30 \cdot 24 + 2$ - first hour of discharging the substorages,

- $ECh \in \mathbb{M} := m \cdot 30 \cdot 24$ - last hour of charging the substorages,
- $EDisch \in \mathbb{M} := (m + 11) \cdot 30 \cdot 24$ - last hour of discharging the substorages,
- $SRC \in \mathbb{H}$ - hourly generation profiles of the electricity sources,
- $AutoD \in \mathbb{H}$ - unit demand for electricity,
- $D = AutoD[i] + NC \cdot EC \in \mathbb{H}$ - cryptocurrency excavator and unit demand for electricity,
- $Rebate$ - rebate,

1.2.3 Variables

- $SBL \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly energy level in the virtual network sub-storage,
- $SL \in \mathbb{R}^{card(\mathbb{H})}$ - hourly energy level in the virtual network storage,
- $SSB \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly sending energy to a virtual sub-storage,
- $ISSB \in \mathbb{B}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly sending energy to a virtual sub-storage indicator,
- $RSB \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly pick up of energy from a virtual sub-storage,
- $IRSB \in \mathbb{B}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly pick up of energy from a virtual sub-storage indicator,
- $SRCM \in \mathbb{R}_+$ - multiplier of the production profile,
- $G \in \mathbb{R}_+^{card(\mathbb{H})}$ - hourly aggregate electricity production,
- $F \in \mathbb{R}_+^{card(\mathbb{H})}$ - hourly energy consumption from the network,
- $SS \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly sending energy to a virtual storage,
- $RS \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly pick up of energy from a virtual storage,

1.3 Mathematical optimization model

1.3.1 Objective

minimize Objective

1.4 Constraints

$$Objective = SRCM \tag{1}$$

$$\begin{aligned} \forall_{h \in \mathbb{H}: h \geq 3 \cdot 30 \cdot 24 + 1} \\ F[h] \leq 0 \end{aligned} \tag{2}$$

$$\begin{array}{c} \forall_{h \in \mathbb{H}} \\ G[h] = SRCM \cdot SRC[h] \end{array} \quad (3)$$

$$\begin{array}{c} \forall_{h \in \mathbb{H}} \\ D[h] = F[h] + G[h] - SS[h] + RS[h] \end{array} \quad (4)$$

$$\begin{array}{c} \forall_{h \in \mathbb{H}} \\ SS[h] \leq G[h] \end{array} \quad (5)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ SSB[h, m] \leq BigM \cdot ISSB[h, m] \end{array} \quad (6)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ SSB[h, m] \geq \frac{1}{BigM} \cdot ISSB[h, m] \end{array} \quad (7)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ RSB[h, m] \leq BigM \cdot IRSB[h, m] \end{array} \quad (8)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ RSB[h, m] \geq \frac{1}{BigM} \cdot IRSB[h, m] \end{array} \quad (9)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ IRSB[h, m] + ISSB[h, m] \leq 1 \end{array} \quad (10)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}: h < SCh[m] \vee h > ECh[m]} \\ SSB[h, m] \leq 0 \end{array} \quad (11)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \\ & \forall_{h \in \mathbb{H}: h < SDis[m] \vee h > EDisch[m]} \\ & RSB[h, m] \leq 0 \end{aligned} \quad (12)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h < SCh[m]} \\ & SBL[h, m] = 0 \end{aligned} \quad (13)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h = SCh[m]} \\ & SBL[h, m] = Rebate \cdot SSB[h, m] - RSB[h, m] \end{aligned} \quad (14)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h \leq Ech[m] \wedge h > SCh[m]} \\ & SBL[h, m] = SBL[h - 1, m] + Rebate \cdot SSB[h, m] - RSB[h, m] \end{aligned} \quad (15)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h \leq EDisch[m] \wedge h > Ech[m]} \\ & SBL[h, m] = SBL[h - 1, m] - RSB[h, m] \end{aligned} \quad (16)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h > EDisch[m]} \\ & SBL[h, m] = SBL[h - 1, m] \end{aligned} \quad (17)$$

$$RS[h] = \sum_{m \in \mathbb{M}: h \geq SDis[m] \wedge h \leq EDisch[m]} \forall_{h \in \mathbb{H}} RSB[h, m] \quad (18)$$

$$SS[h] = \sum_{m \in \mathbb{M}: h \geq SDis[m] \wedge h \leq EDisch[m]} \forall_{h \in \mathbb{H}} SSB[h, m] \quad (19)$$

$$SL[h] = \sum_{m \in M} \forall_{h \in \mathbb{H}} SBL[h, m] \quad (20)$$

2 Number of members

2.1 Introduction

In this section, we will describe the optimization model that was used to generate the results in the *Improvement of operating efficiency of Energy Cooperatives with the use of “crypto-coin mining”* article, for the optimal number of members.

2.2 Variables and parameters

2.2.1 General markings

- \mathbb{R} - set of real numbers,
- \mathbb{R}_+ - set of non-negative real numbers,
- \mathbb{I} - set of integer numbers,
- \mathbb{I}_+ - set of non-negative integer numbers,
- $\mathbb{B} = \{0, 1\}$,
- $card(X)$ - cardinality of set X .

2.2.2 Sets and parameters

- $BigM$ - big real number,
- $\mathbb{H} = \{1, 2, \dots, H\}$ - set of optimization period hours,
- $\mathbb{M} = \{1, 2, \dots, M\}$ - set of optimization period months,
- NC - number of cryptocurrency excavator,
- EC - unit demand of an excavator for electricity,
- $SCh \in \mathbb{M} := (m - 1) \cdot 30 \cdot 24 + 1$ - first hour of charging the substorages,
- $SDis \in \mathbb{M} := (m - 1) \cdot 30 \cdot 24 + 2$ - first hour of discharging the substorages,
- $ECh \in \mathbb{M} := m \cdot 30 \cdot 24$ - last hour of charging the substorages,
- $EDisch \in \mathbb{M} := (m + 11) \cdot 30 \cdot 24$ - last hour of discharging the substorages,
- $SRC \in \mathbb{H}$ - hourly generation profiles of the electricity sources,
- $AutoD \in \mathbb{H}$ - unit demand for electricity,
- $D = AutoD[i] + NC \cdot EC \in \mathbb{H}$ - cryptocurrency excavator and unit demand for electricity,
- $SRCM \in \mathbb{R}_+$ - multiplier of the production profile,
- $Rebate$ - rebate,
- $DF \in \{0.5, 0.6, 0.7, 0.8, 0.9\}$ - demand factor,

2.2.3 Variables

- $SBL \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly energy level in the virtual network sub-storage,
- $SL \in \mathbb{R}^{card(\mathbb{H})}$ - hourly energy level in the virtual network storage,
- $SSB \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly sending energy to a virtual sub-storage,
- $ISSB \in \mathbb{B}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly sending energy to a virtual sub-storage indicator,
- $RSB \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly pick up of energy from a virtual sub-storage,
- $IRSB \in \mathbb{B}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly pick up of energy from a virtual sub-storage indicator,
- $G \in \mathbb{R}_+^{card(\mathbb{H})}$ - hourly aggregate electricity production,
- $F \in \mathbb{R}_+^{card(\mathbb{H})}$ - hourly energy consumption from the network,
- $SS \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly sending energy to a virtual storage,
- $RS \in \mathbb{R}^{card(\mathbb{H})} \times \mathbb{R}^{card(\mathbb{M})}$ - hourly pick up of energy from a virtual storage,
- $MNN \in \mathbb{R}_+$ - number of members,

2.3 Mathematical optimization model

2.3.1 Objective

minimize Objective

2.4 Constraints

$$Objective = MNN \tag{21}$$

$$\begin{aligned} &\forall_{h \in \mathbb{H}: h \geq 3 \cdot 30 \cdot 24 + 1} \\ &F[h] \leq 0 \end{aligned} \tag{22}$$

$$\begin{aligned} &\forall_{h \in \mathbb{H}} \\ &G[h] = CNN \cdot SRCM \cdot SRC[h] \end{aligned} \tag{23}$$

$$\begin{aligned} &\forall_{h \in \mathbb{H}} \\ &CNN \cdot DF \cdot AutoD[h] + NC \cdot EC = F[h] + G[h] - SS[h] + RS[h] \end{aligned} \tag{24}$$

$$\begin{array}{c} \forall_{h \in \mathbb{H}} \\ SS[h] \leq G[h] \end{array} \quad (25)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ SSB[h, m] \leq BigM \cdot ISSB[h, m] \end{array} \quad (26)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ SSB[h, m] \geq \frac{1}{BigM} \cdot ISSB[h, m] \end{array} \quad (27)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ RSB[h, m] \leq BigM \cdot IRSB[h, m] \end{array} \quad (28)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ RSB[h, m] \geq \frac{1}{BigM} \cdot IRSB[h, m] \end{array} \quad (29)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}} \\ IRSB[h, m] + ISSB[h, m] \leq 1 \end{array} \quad (30)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}: h < SCh[m] \vee h > ECh[m]} \\ SSB[h, m] \leq 0 \end{array} \quad (31)$$

$$\begin{array}{c} \forall_{m \in \mathbb{M}} \\ \forall_{h \in \mathbb{H}: h < SDis[m] \vee h > EDisch[m]} \\ RSB[h, m] \leq 0 \end{array} \quad (32)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h < SCh[m]} \\ & SBL[h, m] = 0 \end{aligned} \quad (33)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h = SCh[m]} \\ & SBL[h, m] = Rebate \cdot SSB[h, m] - RSB[h, m] \end{aligned} \quad (34)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h \leq ECh[m] \wedge h > SCh[m]} \\ & SBL[h, m] = SBL[h - 1, m] + Rebate \cdot SSB[h, m] - RSB[h, m] \end{aligned} \quad (35)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h \leq EDisch[m] \wedge h > ECh[m]} \\ & SBL[h, m] = SBL[h - 1, m] - RSB[h, m] \end{aligned} \quad (36)$$

$$\begin{aligned} & \forall_{m \in \mathbb{M}} \forall_{h \in \mathbb{H}: h > EDisch[m]} \\ & SBL[h, m] = SBL[h - 1, m] \end{aligned} \quad (37)$$

$$\begin{aligned} & \forall_{h \in \mathbb{H}} \\ & RS[h] = \sum_{m \in \mathbb{M}: h \geq SDis[m] \wedge h \leq EDisch[m]} RSB[h, m] \end{aligned} \quad (38)$$

$$\begin{aligned} & \forall_{h \in \mathbb{H}} \\ & SS[h] = \sum_{m \in \mathbb{M}: h \geq SDis[m] \wedge h \leq EDisch[m]} SSB[h, m] \end{aligned} \quad (39)$$

$$\begin{aligned} & \forall_{h \in \mathbb{H}} \\ & SL[h] = \sum_{m \in M} SBL[h, m] \end{aligned} \quad (40)$$