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Prediction of Short–term Electrical Energy Consumption in Ceramic Industry

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Abstract: Dominant costs in the ceramic industry. Analysis and optimum predictor design for electrical energy consumption in ceramic industry. Short identification time. Technology and antropology factors in energy management. The measure of predictor efficiency.

Keywords: Grey system, Short series prediction, Energy management, Optimum predictor

1. INTRODUCTION

Because of global competition national and supranational firms are forced to decrease production costs i.e. energy costs, in order to increase their concurrency. Investigations have shown that additional installation of energy sensors in plants and in buildings was not the economically feasible, so some authors suggested build-up of data processing system and data mining procedures [1]. Electrical energy consumption has been found as an important potential in cost decrease in the ceramic industry KIO in Orahovica, Croatia. Escaping penalization for larger electrical energy consumption by means of consumption control and education of workers has been two main activities of the management. Consumption control includes provision for energy consumption prediction by intelligent processing of short-series data.

Investigation of short data series prediction is recognized as one of the dominant factors in adaptive process control as well [2]. We have tried to apply methods from artificial intelligence [3] and from grey system theory [4].

Thus two problems were attacked: i) resolution between human induced and technology induced energy demand and ii) prediction of electric energy demand from short data series.
Generally stated statistical methods demand data series of at least five data for predictor design, and the sixth one for predictor testing.

2. STRATEGIC APPROACH TO ENERGY MANAGEMENT IN CERAMIC INDUSTRY

Ceramic tile production includes: clay cleaning, preparation of mixture from clay, sand, hydrated allumina and water, machine forming of mixture, drying, burning, glazing and again burning. The factory in Orahovica produces 4,2 Mm^2 of ceramic tiles for in- and outdoor application. All production lines are combined in a large single production hall.

The energy efficiency program has been early recognized as an important factor in production management. First concept of energy efficiency represents the fact of possible decreasing of energy consuption while maintaining production output. Second concept represents the fact of being more energetically efficient compared to the expected or standardized way of energy spending. The principal energy efficiency relation can be given as

$$C_s = I_s * Q_s \tag{1}$$

where C_s is energy consumption for a given service s, I_s is energy intensity for unit of the service and Q_s is the measure of total needs for service s. Measurement of energy efficiency can be done from the general approach measuring energy efficiency of energy production, transportation and usage. Technical, behavioristic, temporal and specific changes of energy efficiency factors limit the accuracy of this approach. In our work we propose general approach from the Energy Information Administation that measures actual energy consumption.

Energy consultancy team has been formed in the KIO industry that leads energy system modernization, identifies energy saving methods and monitors all energy management changes. The duration of the project was stated as ten years.

3. IDENTIFICATION AND SHORT -TERM PREDICTION OF PROCESS VARIABLES

Electrical energy consumption is one of the most important part in energy costs in ceramic industry that amounts to 32.5% of production cost [5, 6]. Although not a major cost because of its prise and contracted conditions electrical energy represents a very important process variable. Prediction of electrical energy consumption depends on many aspects, each of which contributes to data variablity and unpredictibility. The expected accuracy of predictions from very short data series has been considered as the most important result of model building. Actually there is no rule in using short data series in prediction, but the most promising looks the theory of grey systems.

The grey system theory has been introduced in China in 1982. [7, 8] and used for scientific research of short data series predictions. It appeared on the assumption that an mathematically unknown (grey) system can be represented with a known (white) system with known and standardized equations.

Models from the grey system theory can be satisfied with three or four data from the observed domain. The solution is represented as [7, 8]:

$$X'^{(0)} (k+1) = (1-e^{a}) (X^{(0)} (1) - b/a) e \exp(- a_{k}), \tag{2}$$

where X' represents the predicted value of X for the next event. The value a_k is the last a in the series of observed values.

4. DESIGN OF THE OPTIMUM GREY SYSTEM PREDICTOR FOR ELECTRIC ENERGY DEMAND

The volatility of the predictor design appears from the prediction frame m(3,4,or 5), time step of the series Δ (1,2, or 3), and prediction weighting factor α (0.4 , 0.5 or 0.6).

Each combination of parameter combinations can be objectively estimated by using Taguchi method and ANOVA analysis. According to actual energy consumption data data the grey system prediction and its error, mean square error and SN ratio were calculated for all nine combinations of grey system parameters were calculated, and given in Table 1

Table 1
Survey of error of grey system predictor with moving frame and different combinations of predictor parameters (A(1,2,3) = m(3,4,5), B(1,2,3)= Δ(1,2,3), C(1,2,3)= α(0.4, 0.5, 0.6))

	Factor			y	MSD	SN
Case	A	B	C			
1	1	1	1	11,96	143,04	21,55
2	1	2	2	26,33	693,27	28,41
3	1	3	3	28,35	803,72	29,05
4	2	1	2	12,88	163,84	22,14
5	2	2	3	6,05	36,60	15,63
6	2	3	1	26,30	691,69	28,40
7	3	1	3	11,25	126,56	21,02
8	3	2	1	5,7	32,49	15,12
9	3	3	2	11,72	137.36	21,38

SN ratios are given for each predictor parameter in Table 2

Table 2
Survey of SN ratios for predictor parameters and corresponding values

Level	Parameter		
	A	B	C
1	**20,04**	18,36	**22,38**
2	20,36	**18,23**	24,35
3	20,49	23,30	22,54
Max – min	0,45	5,07	1,97

Analysis of variance (ANOVA) for moving frame grey system predictor validates the obntained results.

5. RESOLVING AMONG TECHNOLOGY AND HUMAN FACTORS

Using near optimum predictor with A=1, B=1 and C=1 from the previous analysis, data from annual consumption of lighting of production hall, expences for material used for lighting and amount of material used for lighting were analysed for prediction. Testing above data series and corresponding predictions on significnce of variance gives no significance for all data series.

Identification of production costs and corresponding sales on domestic and export market while using material costs as normalizing variable and calculating respective predictions gives rasults as described in Table 3

Table 3
Prediction of the grey system with m=3,4 and α= 0,4 for total sales, material costs, domestic and export sales and corresponding normalizations with the material cost

Position / Year	2001	2002	η
1.Toatal sale prediction, m=3	14.789, -14,50%	16.463; -2,17%	2.32
2.Material costs prediction, m=3	9.620; -26,92%	11.966; 3,60%	2,53
3.Ratio ½ prediction, m=3	**1,539; 9,85%**	**1,383; -5,39%**	**1,69**
4.Prediction domestic sale, m=3	7.218; -33,47%	9.435; 10,50%	2,21
5. Ratio 3/2 prediction, m=3	**0,750; 5,22%**	**0,788; 7,15%**	**1,39**
6.Export sale prediction, m=3	7.601; 3,96%	7.089; -18,17%	1,89
7.Ratio 4/2 prediction, m=3	**0,793; -24,58%**	**0,599; -21,21%**	**1,38**

Rated predictions are bolded and normalized to mean prediction error

$$\eta = \Delta(\text{ input data}) / \varepsilon_{mean} \text{ (prediction error).} \quad (3)$$

6. CONCLUSION

Grey system approach exhibits 4.77% error for short data series and best predictor design. Human factor has been resolved using rated data approach. Sales data were used for such data normalization. A new prediction efficiency measure is proposed as well.

REFERENCES

1. Gregory Cmar: A process for analyzing and identifying patterns of electric energy consumption. European Patent Application 94301386.2 from 28.02.1994.
2. K. Åström, B. Wittenmark, Adaptive Control, Adison-Wesley, Reading, Massachusetts, 1989.
3. K. Doerffner, Konnektionismus, B.G. Teubner Verlag, Stuttgart 1991.
4. Cheng Biao: The Grey Control on Industrial Processes, Journal of Huangshi College, 1, 11-23, 1986.
5. A. Hepbasli, N. Ozalp, Development of energy efficiency and management implementation in the Turkish industrial sector, Energy Conservation and Management Vol. 44, Issue 2, January 2003. pp 231-249
6. J.E. Runnels, M.D. Whyte, Evaluation of Demand-side Management. Proc IEEE 73 10, pp 1489-1495, 1985.
7. Chen Mianyun: Grey Dynamic of the System of a Boring Machine, Journal of Huazhong University of Scxience anf technology, 6, pp7-11, 1982.
8. Deng Julong: Control Problems of Grey Systems, Systems and Control Letters, 5, pp 288-294, 1982.