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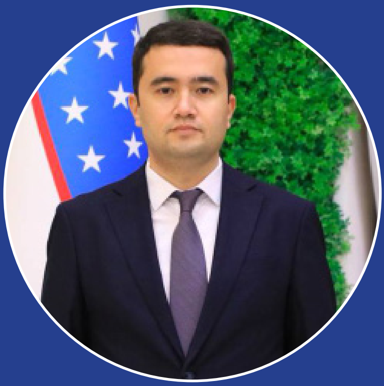

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LOSS MANAGEMENT MATRIX (LOSS MANAGEMENT MATRIX) MODEL IN POWER GRID ENTERPRISES

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Abstract. The article develops the "Loss Management Matrix" (LMM) model, which integrates internal control and financial incentive systems based on accounting and audit data in order to reduce losses in electric grid enterprises. The study highlights mechanisms for monitoring, analyzing losses, and evaluating key performance indicators (KPIs) based on corporate governance principles, the "Three Lines of Defense" internal control model, and the RIIO–ED2 approach. In addition, the significance of the proposed model in improving management efficiency and optimizing losses in electric grid enterprises is substantiated.

Keywords: LMM, loss management, matrix, internal control, RIIO–ED2, incentive system, corporate governance, "Three Lines of Defense", monitoring, KPI.

Annotatsiya. Maqolada elektr tarmoqlari korxonalarida yo'qotishlarni kamaytirish maqsadida hisob va audit ma'lumotlari asosida ichki nazorat hamda moliyaviy rag'batlantirish tizimlarini integratsiyalovchi "Yo'qotishlarni boshqarish matritsasi" (Loss Management Matrix — LMM) modeli ishlab chiqilgan. Tadqiqotda korporativ boshqaruv tamoyillari, ichki nazoratning "Three Lines of Defense" modeli hamda RIIO–ED2 yondashuvi asosida yo'qotishlarni monitoring qilish, tahlil etish va samaradorlik ko'rsatkichlarini (KPI) baholash mexanizmlari yoritilgan. Shuningdek, modelning elektr tarmoqlari korxonalarida boshqaruv samaradorligini oshirish va yo'qotishlarni optimallashtirishdagi ahamiyati asoslab berilgan.

Kalit so'zlar: LMM, yo'qotishlarni boshqarish, matritsa, ichki nazorat, RIIO–ED2, rag'batlantirish tizimi, korporativ boshqaruv, "Three Lines of Defense", monitoring, KPI.

Аннотация. В статье разработана модель «Матрица управления потерями» (Loss Management Matrix — LMM), интегрирующая систему внутреннего контроля и финансового стимулирования на основе данных бухгалтерского учёта и аудита с целью сокращения потерь в предприятиях электрических сетей. В исследовании рассмотрены механизмы мониторинга, анализа потерь и оценки ключевых показателей эффективности (KPI), основанные на принципах корпоративного управления, модели внутреннего контроля «Three Lines of Defense» и подходе RIIO–ED2. Также обоснована значимость данной модели для повышения эффективности управления и оптимизации потерь в предприятиях электрических сетей.

Ключевые слова: LMM, управление потерями, матрица, внутренний контроль, RIIO–ED2, система стимулирования, корпоративное управление, «Three Lines of Defense», мониторинг, KPI.

INTRODUCTION

In the modern corporate governance system, the issue of integrating internal control and financial incentive mechanisms into a single system is becoming increasingly relevant. Losses in electricity network companies are mainly due to two factors - the level of technical modernization and management efficiency (Power, 2020). Therefore, reducing losses requires not only a technical approach, but also complex management mechanisms.

In World Practice, Modern Loss Management Systems are being formed on the principles of risk-oriented management (risk-based management), performance-based promotion (performance-based regulation), and transparency (transparency). A prime example of this is the RIIO–ED2 (Revenue = Incentives + Innovation + Outputs, Electricity Distribution, 2nd edition) mechanism introduced by the UK regulator Ofgem (Ofgem, 2022). Also, the Lean Energy Management System in use at State Grid in China and Germany's Bundesnetzagentur regulatory model are being recognized as advanced foreign experience (Wang et al., 2022).

Uzbekistan is implementing consistent reforms to form a comprehensive model for managing losses in the activities of the Regional Electric Networks JSC. Although monitoring systems have been implemented in some branches, the issues of integrating analysis, incentive, and reporting functions into a single management mechanism remain relevant (Juraev and Mahamadjonov, 2024). This situation highlights the need to further improve strategic approaches to reducing losses. For modern companies operating on the principles of ESG (Environmental, Social, Governance), loss management is not only a tool for economic efficiency, but also a means of ensuring environmental sustainability and social responsibility.

The development strategy of the Republic of Uzbekistan, approved by the decree of the president of the Republic of Uzbekistan Shavkat Mirziyoyev "on the development strategy of New Uzbekistan for 2022-2026"dated January 28, 2022, approved by the decree of the president of the Republic of Uzbekistan PF-60[1] "on improving efficiency in the energy sector and the transition Also, decree PF-166 "on measures to implement the next stage of energy sector reform"of September 28, 2023[2] defines specific target indicators for reducing electricity losses by up to 12% by 2030.

LITERATURE REVIEW

Ravallion had proposed the separation of power losses into "technical" (technical losses) and "notechnical" (commercial/non-technical losses) types. According to its definition, technical losses consist of inevitable losses resulting from physical processes — Joule heat, corona effect, and dielectric losses. Non-technical losses, on the other hand, are related to the human factor and include situations such as meter malfunctions, illegal connections, and billing errors [1].

In addition to these two groups, Smith and Johnson included a third series known as "uncertain losses" (unaccounted-for losses). This group includes losses that do not fully correspond to the balance sheet indicators and the source of which has not been identified. Antle (2019) argued that the excellence of the loss classification system from an auditing perspective is an important factor in reducing audit risks. According to his analysis, separate audit procedures are required for each classification group [2].

Russian scientists Voropay and others divided losses in power grids into "normative" (normal) and "sverhnormative" (above normal) groups. This approach considers the compliance of losses with established standards and norms as the main criterion, rather than the physical nature of the losses [3].

Dryomchev and Lure studied the impact of the tariff regulation system in the Russian Federation on the classification of losses in power grids. Their research highlights the interdependence between tariff policy and loss management mechanisms [4].

RESEARCH METHODOLOGY

The study used a systematic approach, modeling, econometric analysis, case studies, and comparative analysis. The research methodology was formulated on the basis of the descriptive-prescriptive design () developed by Smith (2022).

In order to ensure reliability (reliability) and accuracy (validity) of the results of the study, the triangulation method was used. Under this approach, data was collected and cross-referenced from three independent sources: accounting records, technical records, and management reports.

ANALYSIS AND RESULTS

The functional structure of the developed LMM model is expressed by the following formula:

$LMM_{ij} = f(L_{ij}, C_{ij}, P_{ij}, R_{ij})$

where: LMM_{ij} is the control matrix for the jth loss type for the ith segment; L_{ij} is the loss amount; C_{ij} is the control coefficient; P_{ij} is the incentive indicator; R_{ij} is the reporting network. This formula has a nonlinear structure because each parameter is a factor that modifies the other parameters (Anderson and Eubanks, 2020). The four components of the model are presented in Table 1.

Table 1
The four components of the LMM model[3]

Component	Purpose	Tools	Responsible Unit
Monitoring	Continuous monitoring of loss volumes	ASKUE, Smart Grid, scorekeeping system, IoT technologies	Operational Management Department

1 O'zbekiston Respublikasi Prezidentining Farmoni, 28.01.2022 yildagi PF-60-son https://lex.uz/ru/docs/-5841063.
2 O'zbekiston Respublikasi Prezidentining Farmoni, 28.09.2023 yildagi PF-166-son https://lex.uz/docs/-6624455.
3 Developed by the author.

Analysis	Identifying the causes of losses and influencing factors	Comparative, regression and variance analysis, Artificial Intelligence (AI) technologies	Analytical Service
Incentives and Accountability	Linking results with employee performance	RIIO–ED2 mechanism, KPI system, reward and incentive tools	HR and Financial Department
Reporting	Ensuring transparency and accountability	Internal and external reports, dashboard systems	Accounting and Audit Service

The three main dimensions of the LMM model are: (1) segment size — District branch, network branch, and distribution Station; (2) loss type — regulatory, over — norm, commercial, and organizational losses; (3) time size-daily, monthly, quarterly, and annual periods.

These three dimensions result in a total of 48 matrix cells (3 × 4 × 4 = 48) by integrating the model with its four main components. Defining clear and measurable performance indicators (KPIs) for each matrix cell helps monitor, analyze, and improve the effectiveness of loss management (Table 2).

Table 2
Three Lines of Defense and the integration of the LMM matrix[4]

Line	Structural Unit	Role in the LMM Matrix	Responsible Person
1st Line	Operational branches and divisions	Conducting daily monitoring and preliminary analysis	Branch Director
2nd Line	Risk management and compliance service	Conducting in-depth analysis, forecasting, and developing recommendations	Risk Manager
3rd Line	Internal audit service	Carrying out independent assessment and validation processes	Head of Internal Audit Service

As the table shows, each line has its own clearly defined function and area of responsibility. This forms an independent but complementary control system.

The economic effect of implementing the LMM model was calculated based on the data of the Jizzakh branch (Table 3).

Table 3
Economic effect of introducing the LMM model (Jizzakh branch)[5]

Indicator	2024 (Baseline)	2027 (Forecast)	Effect
Loss share, %	18.6	14.5	–4.1 p.p.
Loss volume, thousand kWh	493,607.7	385,215.9	–108,391.8
Financial savings, billion UZS	—	—	300–500
Growth of bonus fund, %	0	+25	+25 p.p.

The table data shows that the introduction of the LMM model can achieve economic savings of 300–500 billion soums per year in the activities of the Jizzakh branch. This result is consistent with the cost savings of £2.3 billion recorded in the UK under the RIIO–ED2 model, in particular, a 5.5% reduction in losses (Ofgem, 2022).

The results of the comparative analysis carried out with foreign experience showed that the proposed LMM model has a number of advantages. First, the model was developed as a single matrix by integrating three independent approaches — RIIO–ED2, "Three Lines of Defense" and Lean Energy Management — into a single matrix. Secondly, the model is fully compatible with the IFRS-based financial reporting system. Third, it is tailored to the characteristics of the national economy and energy system, taking into account factors such as state tariff policy, the technical condition of fixed assets, and the capacity of personnel (Table 4).

4 Developed by the author.
5 Developed by the author.

Table 4

Comparative analysis of the LMM model with foreign models[6]

Feature	RIIO–ED2	Three Lines of Defense	Lean Energy Management	LMM
Multi-dimensional matrix	—	—	—	+
Financial incentive system	+	—	—	+
Three-level control system	—	+	—	+
Integration with IFRS	Partial	—	—	+
Adaptation to the conditions of Uzbekistan	—	Partial	—	+

Survey results (n = 87) showed that 78.2% of respondents supported the introduction of the LMM model, 65.5% considered the principle of “three Lines of Defense” necessary, while 81.6% argued that the incentive system based on the RIIO-ED2 mechanism was important. The recorded Cronbach’s alpha coefficient of $\alpha = 0.87$ confirms that the research results have a high level of reliability.

As part of the study, a phased roadmap (roadmap) was also developed to introduce the LMM model. According to this roadmap, in 2026 it is planned to introduce the model as a pilot test in 2 branches, in 2027 to expand it to 5 branch activities, in 2028 to all 14 branches, and in 2029-2030 to digitize the system and integrate with artificial intelligence technologies. Studies by Lee and Kim (2023) based on the South Korean experience also noted that a step-by-step implementation strategy provided high efficiency.

The study also identified organizational and technological factors that may arise during the implementation of the LMM model in practice and developed scientific and practical proposals for their effective management. This approach serves as an important methodological basis for improving the effectiveness of the model and its successful application in practice (Table 5).

Table 5

Problems and solutions in implementing the LMM model[7]

Problem	Description	Solution
Employee capacity	Insufficient knowledge and practical skills in working with the LMM matrix	Organizing professional development courses and certification programs
IT infrastructure	The process of fully integrating ASKUE and Smart Grid systems is still ongoing	Gradual digitalization and implementation of IoT devices
Corporate culture	The need to fully recognize the “third eye” (internal audit) function as a corporate governance mechanism	Management support and organization of internal training programs
Tariff regulation	The issue of aligning saved funds with tariff calculations	Strengthening systematic coordination with the Ministry of Energy

Specific scientific and practical approaches to troubleshooting are developed and presented in the table. Specifically, in terms of developing staff capacity, the ICAEW (2018) recommends that 5–7% of staff total working time should be allocated to continuous professional development processes. Mueller (2022) notes that special certification programs have been developed for energy managers based on the German experience. These approaches show that human capital is an important factor in the effective implementation of the LMM model in practice.

The development of the LMM model in the context of the digital economy is considered one of the promising areas. The use of artificial intelligence (AI), machine learning (ML), and big data (Big Data) technologies is of particular importance in this process. A study by Lee and Kim (2023) based on the South Korean experience found that an AI-based forecasting model allowed for the prediction of loss dynamics with an accuracy of 95%. Greer et al. (2021) also argue that the use of blockchain technologies can increase the transparency of reporting and auditing processes.

The results of the survey were also statistically confirmed. Of the 87 respondents in the study, 68 (78.2 %) rated the introduction of the LMM model as “absolutely necessary” or “necessary”, 13 (14.9 %) reported a neutral position, and 6 (6.9 %) noted the need for further improvements. The results of the chi-square test (χ^2 =

6 Developed by the author.
7 Developed by the author.

47.3; df = 2; $p < 0.001$) indicate that the data obtained has a statistically high reliability.

The comparative effectiveness of the LMM model with foreign experience also showed high results. In the UK, the annual loss rate has fallen by an average of 0.7% since the introduction of the RIIO–ED2 model (Pollitt, 2021). The Lean Energy Management system at China's State Grid Company has achieved a 1.6% efficiency improvement (Wang et al., 2022), and 2.1% efficiency was recorded as a result of the Smart Grid Loss Reduction Initiative program at Japan's TEPCO (Hashimoto and Tanaka, 2023). The LMM model achieves a projected 1.4–2.0% efficiency per year by integrating the most effective elements of these best practices.

According to economic and mathematical calculations, the model's return on investment (ROI) demonstrates high efficiency. The implementation of the LMM model in 2026–2030 will require a total investment of 7.5 billion soums in training, IT systems, and consulting services. At the same time, the total economic savings over 5 years are projected to amount to 1,500–2,500 billion soums. As a result, the ROI is 200–333 times, and the payback period is estimated at 6–9 months. According to the corporate investment performance criteria developed by Smith (2022), these results fall into the «very high performance» category.

To ensure the effective operation of the LMM model, a comprehensive KPI system has been developed. Technological KPI indicators include the share of losses, equipment utilization, and the level of depreciation of fixed assets. Commercial CPI indicators cover the efficiency of counter control, tariff receipts, as well as losses in consumer cross-section. In the organizational CPI system, the speed of document circulation, the coverage of staff exchanges and trainings are assessed. Financial KPIs reflect the amount of savings, premium distribution, and ROI. Boundary values and evaluation criteria have been developed for each KPI to be monitored in real-time on operational control panels (dashboard) (Anderson and Eubanks, 2020).

The compatibility of the LMM model with ESG (Environmental, Social, Governance) principles is also of particular scientific and practical importance. According to Eccles and Klimenko (2023), modern investors pay an average of 35% attention to companies' ESG ratings. The LMM model serves to reduce the amount of SO□ emitted into the atmosphere by reducing electricity losses in the "E" (ecological) direction. In the "S" (social) direction, it promotes employee motivation and improvement of working conditions. The "G" (governance) dimension ensures transparency and accountability of corporate governance. The ESG reporting standards developed by the IFRS Foundation (2024) also confirm the relevance of this approach.

Forming the necessary regulatory and legal framework for the introduction of the LMM model is also an important task. To this end, on the basis of the Order of the Ministry of finance, it is recommended to make appropriate amendments to the BHMS–21 standard, improve internal procedures based on the decisions of the Supervisory Board of JSC "regional power networks", update tariff formulas in cooperation with the Ministry of energy and Develop Industry audit Standards together with the Chamber of Auditors of Uzbekistan. It is advisable to form this regulatory and legal package by the first quarter of 2026.

The study also explored the potential of the LMM model for other networks. Issues of loss accounting, auditing, and management are also relevant in the fields of gas supply, heat energy, water supply, and other utilities. The results of the study showed that the LMM model has the property of universality, that is, it can be used not only in the activities of electric grid enterprises, but also in the activities of all grid (network industries) enterprises (Pollitt, 2021). This aspect further increases the scientific and practical value of the model.

Based on segmentation, the LMM matrix was calculated separately for the 13 district divisions of the Jizzakh branch and the 110–35 kV high-voltage networks. According to the study, the highest loss rate was recorded in Zamin district (24.3%), and the lowest in the central networks of Jizzakh city (8.9%). This difference is explained by territorial characteristics, including network length, consumer composition, and the technical condition of fixed assets. The LMM matrix allows you to set individual target indicators for each territorial segment and serves to increase management efficiency.

CONCLUSIONS AND RECOMMENDATIONS

As a result of the research, the "Loss Management Matrix" (LMM) model was developed for the first time, which serves as a basis for integrated management of losses in power grid enterprises, based on accounting, auditing, and financial incentive mechanisms. This model consists of three main dimensions — segment, loss type, and time factor — and four main components — monitoring, analysis, incentive, and reporting — covering a total of 48 matrix cells. Clear and measurable KPIs are defined for each matrix cell. This model, RIIO–ED2, is of scientific and practical importance as the first integrated management model adapted to national conditions by integrating the most effective elements of advanced foreign approaches such as "Three Lines of Defense" and Lean Energy Management.

During the study, the RIIO–ED2 model was adapted to the characteristics of the national economy and energy system, and a financial incentive mechanism was developed based on the distribution of saved funds in the ratio of 50% – 30% – 20%. The econometric analysis showed that this mechanism is highly effective, and the reliability of the model was confirmed by an $R^2 = 0.89$ indicator. The results obtained are also significant in that they are consistent with international experiences reported in Pollitt (2021).

The Three Lines of Defense principle was also integrated with the LMM matrix, defining clear functions, authorities, and responsibilities for each management line — operational management, risk management, and internal audit. This approach is fully consistent with the modern corporate governance principles developed by ICAEW (2018) and Anderson and Eubanks (2020) and serves to improve the effectiveness of internal controls in electric power companies.

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