ŽILINSKÁ UNIVERZITA V ŽILINE
Výskumné centrum
UNIZA

IPESOFT 30 YEARS OF SMART SOLUTIONS

ZBORNÍK

Problematika volatility trhu energetických komodít
Vedecká konferencia Žilina, Slovensko

The issue of the energy commodity market volatility
Scientific conference Zilina, Slovakia
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OBSAH

Návrh architektúry informačného systému

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***Abstract*— V článku predstavíme spracovanie popisu architektúry informačného systému pre lokalizáciu v lokalite UNIZA. Informačný systém bude slúžiť na uľahčenie navigácie návštevníkov v areáli univerzity.**

Keywords—Informačný systém, Životný cyklus vývoja systému, UNIZA

I. INTRODUCTION *(HEADING 1)*

V súčasnej dobe rýchleho technologického pokroku a neustáleho rozširovania digitálneho prostredia, zohrávajú informačné systémy kľúčovú úlohu v rôznych odvetviach a organizáciách. Tieto systémy sa stali neoddeliteľnou súčasťou moderného podnikania a poskytujú základ pre efektívne riadenie a správu informácií. Návrh a implementácia informačného systému je kritickým krokom v procese zabezpečenia, že organizácia má nástroje na získavanie, uchovávanie, spracovávanie a využívanie dôležitých informácií, ktoré potrebuje na svoju činnosť.

Tento článok sa venuje práve tejto dôležitej fáze vývoja informačných systémov - návrhu architektúry. Architektúra informačného systému predstavuje jadro celého systému a je zodpovedná za definovanie štruktúry, komponentov a vzájomných vzťahov medzi nimi. Správny návrh architektúry je rozhodujúci pre dosiahnutie efektívnosti, spoľahlivosti, škálovateľnosti a bezpečnosti informačného systému.

V tomto článku sa budeme venovať kľúčovým aspektom návrhu architektúry informačného systému. Preskúmame rôzne prístupy a metódy, ktoré sa používajú pri tomto procese.

Cieľom tohto článku je poskytnúť ucelený pohľad na návrh architektúry informačného systému.

II. VÝVOJ INFORMAČNÉHO SYSTÉMU

Vývoj informačného systému (IS) je komplexný proces pri ktorom je vhodné dodržiavať štandardné postupy. V našej práci budem vychádzať zo Životného cyklu vývoja systému (SDLC – System Development Life Cycle) a uplatňujú sa nasledovné fázy [1]:

- **Definícia potrieb:** Identifikujte a analyzujte potreby a požiadavky používateľov a organizácie. To zahŕňa pochopenie účelu IS, jeho cieľov a obmedzení.
- **Plánovanie projektu:** Stanovuje rozsah projektu, cieľové termíny, rozpočet a zdroje. Tvorí sa projektový plán a harmonogram, ktorý zohľadňuje všetky kroky vývoja.
- **Analýza:** Analyzuje požiadavky – t.j. funkčné a nefunkčné špecifikácie. Vytvoria sa modely dát, procesov a používateľské rozhrania.
- **Návrh architektúry:** Navrhne sa architektúra, vrátane komponentov, databázy a vzájomných vzťahov.
- **Vývoj:** Na základe návrhu sa IS implementuje, jeho jednotlivé časti sa testujú a integrujú do väčších celkov.
- **Testovanie:** Testujú sa jednotlivé komponenty, integrita systémov, ako aj testy používateľskej akceptácie. Prebieha oprava a vylepšovanie systému.
- **Implementácia:** Nasadenie IS do prevádzky.
- **Údržba a podpora:** Zabezpečujú správne fungovanie IS v prevádzke na základe spätnej väzby od používateľov systému.
- **Školenie a dokumentácia:** spracovanie dokumentácie pre používanie a správu systému.

Tento postup môže byť prispôsobený podľa špecifických potrieb projektu a typu informačného systému, ktorý sa vyvíja. Vývoj informačného systému je dynamický proces, a preto by mal byť pružný a reagovať na zmeny a nové požiadavky, keď sa objavia [2].

V tomto článku predstavíme proces vývoja IS pre lokalizáciu v lokalite Žilinskej univerzity v Žiline (UNIZA). V súčasnosti neexistuje interaktívny spôsob navigácie po areáli. Spracovanie popisu architektúry je urobené na základe normy ISO/IEC/IEEE 42010 :2011.

III. VZŤAHY A ZÁUJMY K IS

V kontexte vývoja systémov sú zainteresované strany ľudia, ktorí buď sami alebo prostredníctvom organizácie, ktorú zastupujú, majú akýkoľvek vzťah k vyvíjanému systému. Používatelia sú ľudia, ktorí so systémom pravidelne prichádzať do styku. V závislosti od povahy vyvíjaného IS môže vývojový tím zahŕňať systémových analytikov a programátorov a ďalších [3].

A. Zainteresované strany a ich záujmy

Pri vývoji informačného systému existuje niekoľko zainteresovaných strán, ktoré majú rôzne záujmy a požiadavky. Identifikácia a riadenie týchto zainteresovaných strán je dôležitou súčasťou pri vývoji IS [4].

Pri vývoji IS na lokalizáciu po UNIZA sú zohľadnené nasledovné zainteresované strany:

- Študenti,
- Zamestnanci
- Verejnosť
- Vývojári, programátori, testeri
- Správca IS

Tieto zainteresované strany majú voči vyvíjanému systému rôzne záujmy. Medzi hlavné záujmy patria:

- **Intuitívnosť (I)** - rýchla orientácia v poskytnutých informáciách
- **Udržateľnosť (U) -** návrh IS, ktorý umožní jednoduché rozšírenie funkcionalít s minimalizáciou času potrebného pre rozšírenie
- **Dostupnosť (D)** – pre širšie spektrum spoločnosti (multijazyčnosť, prispôsobenie pre zrakovo znevýhodnených), platformová nezávislosť (webová aplikácia)
- **Funkčnosť (F)** – stabilita systému
- **Spoľahlivosť (S) –** správne označenia tabúľ

Závislosť medzi záujmami jednotlivých zainteresovaných strán sú uvedené v tabuľke I.

TABUĽKA I.

Vzťah/ záujem	**Sledovateľnosť záujmov**				
	Študenti	***Zamest.***	***Verejnosť***	***Vývojári***	***Správca IS***
I	X	X	X	-	-
U	-	-	-	X	X
D	X	-	X	X	X
F	X	X	X	X	X
S	X	-	X	-	-

IV. ARCHITEKTÚRA SYSTÉMU

Architektúra akéhokoľvek systému vytvoreného človekom opisuje celkovú štruktúru systému, jeho hlavné komponenty a spôsob, akým sú tieto komponenty navzájom prepojené.

Architektúra poskytuje štruktúrovaný pohľad na jednotlivé aspekty a podporuje rozhodovanie o nových, respektíve optimalizácie existujúcich riešení. Detailizuje štruktúry a vzťahy vo vnútri organizácie, jeho biznis modely, spôsob, akým organizácia pracuje a ako a akým spôsobom informácie, informačné systémy a technológie podporujú biznis zámery a ciele.

Hlavnou úlohou systémovej architektúry je zvládnutie zložitosti a veľkosti informačných systémov. Architektúra znázorňuje dôležité rozhodnutia o návrhu, ktoré už boli urobené.

IS je vždy tvorený z troch základných hľadísk [5], [6]:

- Biznis architektúra
- Softvérová architektúra
- Hardvérová architektúra

V ďalších častiach je uvedený samotný návrh IS.

A. Biznis model

V tejto časti budú bližšie poskytnuté informácie o všetkých potrebných aktivitách a procesoch spojených s navigáciou po areáli UNIZA.

1) Textový model – pôvodný popis procesov AsIs

Proces navigácie:

Po vstupe do areálu UNIZA môže navigácia prebiehať pomocou rôznych navigačných prvkov. Navigujúca sa osoba sa môže orientovať podľa máp rozmiestnených po areáli. Toto vyžaduje dobrú pamäť a zahŕňa mapovanie reálnych objektov do značiek rôznej farby, tvaru, štruktúry a veľkosti. Po nájdení tabule s mapou, potrebuje osoba identifikovať označené objekty a po rozhliadnutí sa zistiť na akom mieste v areáli sa práve nachádza. Následne potrebuje na mape nájsť svoj cieľ a podľa odhadnutej aktuálnej polohy a polohy cieľu sa môže vydať daným smerom. Orientácia podľa tabúľ nezahŕňa grafické znázornenie objektov. Navigačná tabuľa pozostáva z názvu objektu/objektov, alebo jeho skráteného tvaru a šípky ukazujúcej smer k nemu/ním. Osoba hľadajúca budovy týmto spôsobom prechádza od tabule k tabuli v smere šípok až kým nedosiahne svoj cieľ. Identifikácia súčasnej polohy teda nie je nutná. Ďalší spôsob orientácie je modernejší, kde je možné využiť statickú mapu na webe. Pri orientovaní sa podľa tejto online mapy, nemôže osoba zaručene určiť svoju aktuálnu polohu z dôvodu jej neoznačenia na mape, musí si vystačiť s okolitými objektami a ich identifikácie. Nie je možné presne zistiť ako dlho bude človeku trvať cesta a ako ďaleko je cieľ.

Definované podprocesy:

- Proces orientácie podľa offline mapy
- Proces orientácie podľa tabúľ
- Proces orientácie podľa mapy na webe

- Proces navigácie podľa pamäti

2) Štruktúrovaný popis AsIs procesov

Podproces orientácia podľa smerových tabúľ:

Popis procesu: Tento proces opisuje orientáciu sa v areáli UNIZA podľa orientačných tabúľ. Týmto spôsobom sa orientujú hlavne prváci a ľudia, ktorí nepoznajú areál. Človek vstúpi do areálu a obzerá sa aby našiel orientačnú tabuľu. Pozrie sa na ňu a vydá sa smerom kadiaľ ukazuje. Po ceste, keď narazí na ďalšiu tabuľu, upraví smer. Po istom čase dorazí do cieľa.

Podklady pre modelovanie procesu:

- Vlastníci procesu
- Novo prijatí študenti
- Študenti hľadajúci objekt, ktorý ešte nenavštívili
- verejnosť (nepoznajú areál)
- Zamestnanci UNIZA (novo zamestnaní)

Vstupy:

- Orientačné tabule

Transformácia:

- príchod do areálu
- zistenie aktuálnej polohy podľa tabúľ
- vydanie sa smerom k cieľu
- presun na základe tabúľ
- príchod k cieľovému objektu

Výstupy:

- Príchod na cieľové miesto
- Nový poznatok o umiestnení objektov

Nedostatky:

- Človek nevie svoju aktuálnu polohu, ani ako dlho to bude trvať a ako ďaleko to je.
- Taktiež sa môže stratiť, ak je tabuľa neaktuálna alebo zle viditeľná.

Takýmto spôsobom je potrebné mať rozpísané všetky definované podprocesy. Na základe týchto informácií sa následne spracuje grafický popis pôvodného procesu.

3) Grafický popis AsIs procesov

Podproces orientácie podľa pamäti je graficky znázornený na nasledujúcom obrázku.

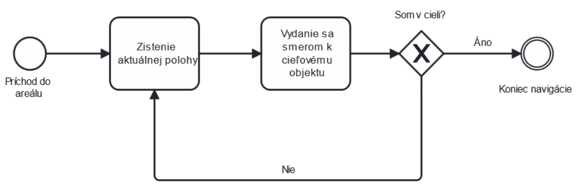


Figure 1. Grafický popis AsIs podprocesu – orientácia podľa pamäti.

Podproces orientácie podľa smerových tabúľ je na obrázku č. 2.

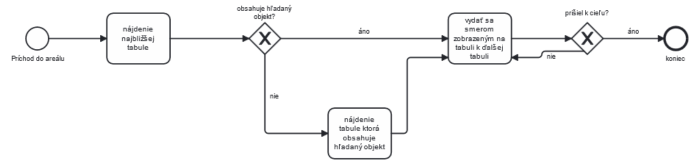


Figure 2. Grafický popis AsIs podprocesu – orientácia podľa smerových tabúľ

Podproces orientácia podľa mapy na webe je na obrázku č. 3.

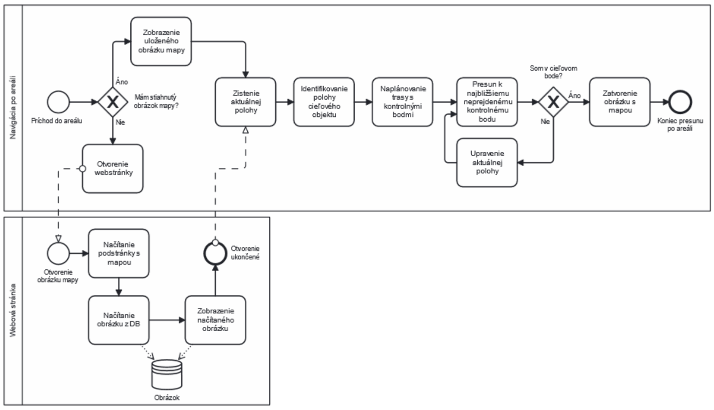


Figure 3. Grafický popis AsIs podprocesu – orientácia podľa mapy na webe

Posledný podproces orientácia podľa fyzickej tabule s mapou je graficky znázornený na obrázku č. 4.

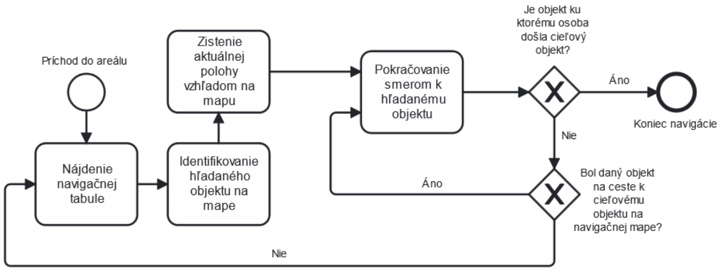


Figure 4. Grafický popis AsIs podprocesu – orientácia podľa fyzickej tabule s mapou

B. *Biznis návrh inovovaných procesov ToBe*

Na základe zisteného skutočného stavu boli navrhnuté inovované ToBe procesy, ktoré sa opäť najskôr zaznamenajú vo forme štruktúrovaného opisu, z nich sa spracuje grafický popis a nakoniec sa spracuje funkčná špecifikácia procesov.

1) Štrukturovaný opis inovovaných procesov

Hlavné procesy:

- Proces orientácie podľa smerových tabúľ
- Proces navigovania pomocou mobilnej aplikácie

- Proces orientácie podľa fyzickej elektronickej tabule s mapou

Vlastníci procesov:

- Novo prijatí študenti
- Študenti hľadajúci objekt, ktorý ešte nenavštívili
- ľudia (nepoznajú areál)
- Zamestnanci UNIZA (novo zamestnaní)

Inovovaný proces navigovania pomocou mobilnej aplikácie

Popis : Po príchode používateľa do areálu UNIZA si v telefóne zapne mobilnú aplikáciu. Tato aplikácia pri spustení vykoná prvotnú inicializáciu pri ktorej sa zapne funkciu GPS a načíta sa mapa areálu UNIZA taktiež sa zisti aktuálna poloha používateľa. Následne vyzve k nastaveniu cieľového objektu(budova, parkovisko, ...) a po jeho zadaní sa vytvorí a zobrazí výsledná trasa presunu zo štartovacieho bodu do cieľového bodu. Okrem celkovej trasy bude zobrazovať aj najbližší kontrolný bod ku ktorému sa používateľ má presunúť. Po príchode na daný bod si aplikácia prekresli neprejdenú trasu a overí či tento bod je cieľový ak áno tak informuje o tom používateľa ktorý následne môže aplikáciu zatvoriť. Ak daný bod nie je cieľové miesto tak aplikácia zobrazí ďalší najbližší kontrolný bod do ktorého sa má používateľ presunúť a takto to budeme opakovať pokiaľ neprídeme k cieľovému miestu.

Vstupy :

- Príchod do areálu
- Nainštalovaná mobilná aplikácia

Proces :

- Spustenie aplikácie
- Prvotná inicializácia aplikácie
- Zadanie cieľového objektu
- Zostavenie trasy na presun
- Presun k cieľovému objektu
- Aktualizovanie trasy v aplikácii
- Zatvorenie aplikácie

Výstupy:

- Príchod do cieľového miesta
- Získanie nových poznatkov pre navigáciu po areáli

Vlastníci procesu:

- Študenti a zamestnanci
- Verejnosť
- IS - Mobilná aplikácia

Rovnakým spôsobom sa spracujú aj zvyšne inovované ToBe podprocesy.

2) Grafický popis inovovaných procesov

Na základe štruktúrovane spracovaných opisov procesov sa následne urobí grafický popis týchto procesov.

Na obrázku č. 5 je znázornený ToBe proces orientácie podľa smerových tabúľ.

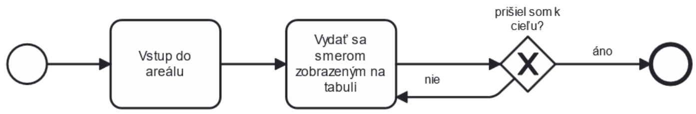


Figure 5. Inovovaný proces – orientácia podľa smerových tabúľ

Obrázok č. 6 znázorňuje ToBe process navigovania pomocou mobilnej aplikácie.

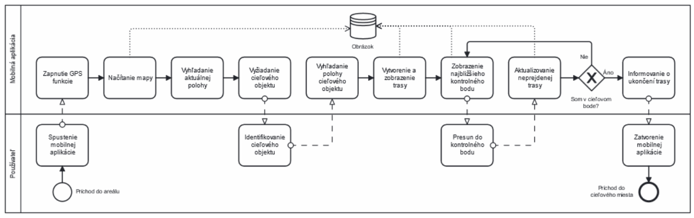


Figure 6. Inovovaný proces – navigovanie pomocou mobilnej aplikácie

Ďalší proces je na obrázku č. 7.

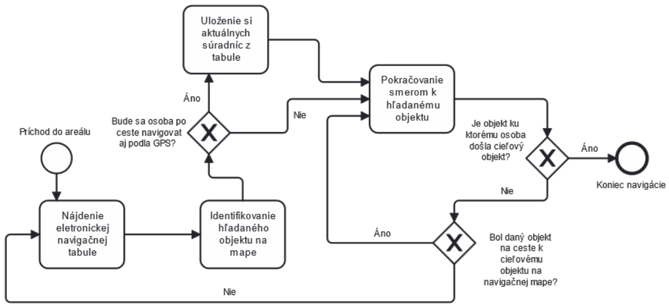


Figure 7. Inovovaný proces – orientácia podľa elektonickej tabule s mapou

3) Funkčná špecifikácia procesov

Na základe zistených skutočností bolo definovaných 6 funkčných požiadaviek na vyvíjaný systém.

- Podpora GPS lokalizácie
- Poskytovanie aplikácie vo viacerých jazykoch
- Pokrytie
- Podpora viacerých jazykov v elektronickej tabuli
- Prispôsobovanie osvetlenia tabule podľa okolitej viditeľnosti

a) Rozpis požiadavie

Každá požiadavka uvedená vyššie bola rozpísaná nasledovným spôsobom:

Názov požiadavky: podporovanie GPS lokalizácie

Popis: Aplikácia bude schopná zistiť aktuálnu polohu používateľa.

Vstup: Používateľ má zapnutú aplikáciu a nastavené povolenie pre získavanie polohy.

Zobrazenie: Používateľovi sa po zapnutí aplikácie zobrazí okno v ktorom potvrdí povolenie získavať aktuálnu polohu.

Podrobná sekvencia systémového spracovania: Aplikácia po zapnutí spustí prvotnú inicializáciu počas ktorej ak ma povolenie od užívateľa zapne funkciu na lokalizáciu polohy a následne zistí aktuálnu polohu používateľa. Táto poloha sa bude ďalej používať pri návrhu trasy presunu.

Výstup: Výstupom je aktuálna pozícia v areáli UNIZA.

Obmedzenia: Používateľ musí mať dostatočne silný signál.

V. SOFTVÉROVÉ HĽADISKO

Softvérové hľadisko pri vývoji informačného systému zahŕňa všetky aspekty týkajúce sa návrhu, vývoja, implementácie a údržby softvéru, ktorý bude súčasťou informačného systému. To znamená, že sa zameriava na technické a programátorské aspekty tvorby informačného systému, ako aj na funkčnosť a výkon softvéru.

K zobrazeniu hľadiska sa využívajú UML diagram, Use Case diagram a BPMN diagramy.

A. Architektonický štýl

V informačnom systéme budú využívané tri štýly softvérovej architektúry, a to klient/server architektúra, model-view-viewmodel (MVVM) architektúra a objektovo-orientovaná architektúra.

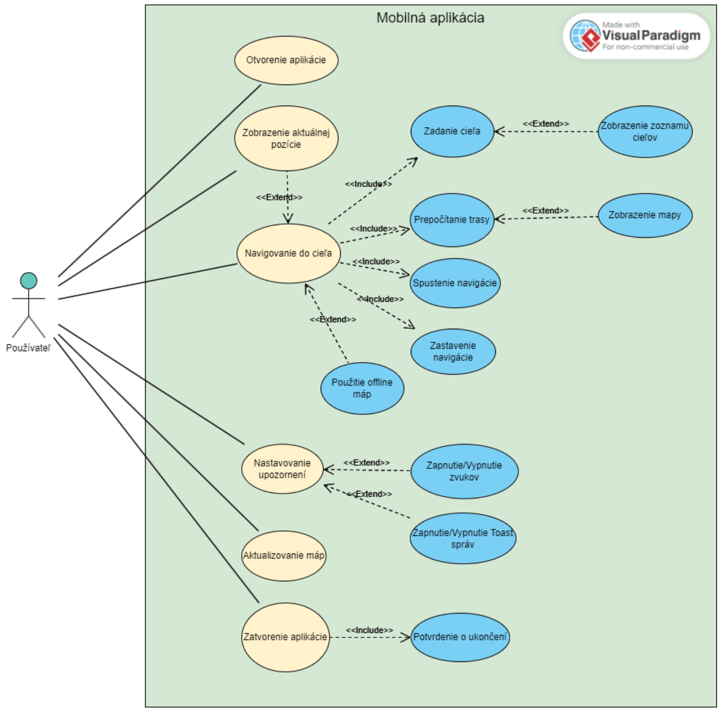
Aplikácia bude pracovať s databázou umiestnení a úložiskom máp, preto jej základom bude klient-server architektúra. Klientska časť bude implementovaná ako mobilná aplikácia, kde sa budú mapy aktualizovať zo servera a následne budú použiteľné pre používateľa pri navigácií. Komunikácia medzi klientom a serverom bude zabezpečená MVVM architektúrou softvéru. Obe spomenuté architektúry sú objektovo orientované, preto pre uľahčenie prepojenia medzi nimi a lepší vývoj softvéru sa taktiež použije objektovo-orientovaná architektúra.

B. Návrhový model softvéru

Pre back-end a front-end softvéru bol zvolený programovací jazyk Flutter od spoločnosti Google, ktorý sa využíva na vývoj aplikácií pre Android a IOS. V klientskej časti budú použité rôzne návrhové vzory. Použije sa aj návrhový vzor Bloc, ktorý využíva streamy na riadenie stavu. Je to najznámejší vzor vo Flutter. Kód je rozdelený na tri časti: view, bloc a repository. View je zodpovedný za vykreslenie používateľského rozhrania, bloc predstavuje stav aplikácie pomocou streamov a repository je zodpovedné za načítavanie a ukladanie údajov. Toto by malo zabezpečiť plynulý chod softvéru a lepší finálny výzor aplikácie.

C. Diagram prípadov použitia ToBe procesu navigovania pomocou mobilnej aplikácie

Nasledujúci obrázok znázorňuje príklad znázornenia ToBe procesu prostredníctvom Use Case diagramu.



VI. FINALIZÁCIA NÁVRHU PROJEKTU

Vo finalizácií návrhu projektu je zahrnutá implementácia, testovanie, spôsob nasadenia informačného systému

A. Návrh pre realizáciu kódovania

Pri implementácii sa bude využívať kombinácia architektúr: klient/server, MVVM a objektovo-orientovaná. Softvér bude implementovaný v programovacom jazyku Flutter.

B. Testovacie scenáre

V nasledujúcej časti popíšeme základné testovacie scenáre informačného systému, jednotlivé kroky testovacích scenárov a očakávané výsledky.

Pre účely nášho systému boli navrhnuté nasledovné testovacie scenáre k mobilnej aplikácii:

- Kontrola funkčnosti vyhľadávania
- Kontrola funkčnosti navigácie
- Kontrola funkcionality upozornení
- Kontrola funkcionality offline máp
- Kontrola funkcionality rôzneho typu použiteľnosti
- Kontrola funkcionality aplikácie

Testovacie scenáre k využitiu smerových tabúľ:

- Testovanie prístupnosti

- Testovanie orientácie
- Testovanie presnosti

Testovací scenár k využitiu elektronickej fyzickej tabule s mapou:

- Kontrola funkčnosti užívateľského rozhrania
- Kontrola funkčnosti vyhľadávania
- Kontrola funkčnosti zoomovania a pohybe po mape

VII. ZÁVER

Cieľom bolo vytvoriť informačný systém na pomoc jednotlivcom v rámci univerzitného areálu UNIZA prostredníctvom poskytovania lokalizačných a navigačných služieb. Systém uľahčí lokalizáciu študentov, zamestnancov a návštevníkov v areáli univerzity tým, že ponúkne funkcie, ako je navigácia a vyhľadávanie konkrétnych miest.

V práci bol spracovaný podrobný návrh vývoja IS.

Na základe analýzy boli spracované súčasné procesy AsIs, z ktorých vyplynuli inovanové ToBe procesy. Výsledkom tejto činnosti bolo definovanie funkčných požiadaviek. Ku každej požiadavke boli priradené príslušné vstupy, výstupy a podrobný opis. Tým sa zabezpečila identifikácia a zdokumentovanie všetkých potrebných funkcií.

Z architektonického hľadiska sa vytvoril návrh softvéru. Vyhodnotilo sa, že v systéme sa využije viacero softvérových architektúr. Tieto architektúry zahŕňať architektúru klient/server, architektúru Model-View-ViewModel (MVVM) a objektovo orientované návrhy.

Vo fáze finalizácie návrhu vývoja IS prebehla implementácii kódovania, testovaniu softvéru a spracovanie dokumentácie. Vytvorili sa testovacie scenáre, ktoré pokryli všetky možné prípady použitia a zabezpečili dôkladné otestovanie funkčnosti systému.

Výsledkom úsilia je návrh IS na lokalizáciu v lokalite UNIZA. Ide o komplexný lokalizačný a navigačný systém pre UNIZA, ktorý zlepší orientáciu študentov, zamestnancov a návštevníkov univerzity a zároveň im poskytne potrebné informácie a usmernenia.

POĎAKOVANIE

Táto publikácia vznikla vďaka podpore v rámci Operačného programu Integrovaná infraštruktúra pre projekt: Podpora výskumno-vývojových kapacít na poli generovania pokročilých softvérových nástrojov určených na zvýšenie odolnosti hospodárskych subjektov pred nadmernou volatilitou trhu s energetickými komoditami, kód ITMS2014+ 313011BUK9, spolufinancovaný zo zdrojov Európskeho fondu regionálneho rozvoja.

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Krátkodobá predikcia intenzity slnečného žiarenia za účelom efektívneho obchodovania s elektrickou energiou

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***Abstrakt*–Hlavným prínosom príspevku je návrh systému pre krátkodobú predpoveď výkonu fotovoltickej elektrárne využitím neurónovej siete, ktorá bude založená na využívaní údajov a dát získavaných v mieste inštalácie elektrárne. Takáto predpoveď umožní spoluprácu fotovoltických elektrární s vybranými typmi zdrojov nie len v rámci inteligentných budov, ale aj v rámci virtuálnych výrobných zdrojov elektrickej energie. Doplnkové zdroje (napr. plynové a parné turbíny alebo kogeneračné jednotky) budú môcť na základe veľmi krátkodobej predpovede výkonu fotovoltických elektrární meniť svoj výkon a tak vyrovnávať odchýlky od plánovaného diagramu spotreby inteligentnej budovy resp. výrobného diagramu virtuálneho bloku. Okrem toho kvalitná predikcia výkonu fotovoltických elektrární umožní nasadenie väčšieho výkonu týchto elektrární do elektrizačnej sústavy. Presnejšia predpoveď veľkosti elektrického výkonu vyrábaného vo fotovoltickej elektrárni a najmä znalosť očakávaných dynamických zmien tohto výkonu pre krátke časové intervaly výrazným spôsobom prispeje ku zlepšeniu kvality riadenia energetického manažmentu inteligentných budov, inteligentných miest a v neposlednom rade ku zlepšeniu stability a bezpečnosti prevádzky elektrizačných sústav a k výraznému zlepšeniu kvality ich dispečerského riadenia. Tým sa zároveň zníži potreba na množstvo regulačnej elektriny a zároveň sa umožní vytvárať priestor pre zlepšenie energetickej efektívnosti, jednak na strane výroby ale aj prenosu a distribúcie elektrickej energie.**

I. ÚVOD

Prírodné podmienky v Slovenskej republike sú priaznivé pre trvalé využívanie slnečného žiarenia ako zdroja elektriny. Máme firmy a odborníkov, ktorí vedia vyrobiť slnečný kremík, kvalitné fotovoltické články a panely, navrhnúť, vyprojektovať a inštalovať fotovoltický systém. Vzhľadom k miestnym podmienkam sa však zatiaľ orientujú takmer výhradne na export. Ak naša spoločnosť dospeje k rozhodnutiu a rýchlejšiemu presadzovaniu tohto perspektívneho zdroja energie v SR, potom sa nám podarí prekonať doterajšie bariéry (vysoké investičné náklady a cenu) a môžeme dohnať vyspelé krajiny, ktoré už tieto bariéry s úspechom prekonali a vstupujú tak do energetiky zajtrajška, založenej na požiadavke trvalo udržateľného života.

Základom veľmi krátkodobej predpovede intenzity toku žiarenia je presný popis časového vývoja oblačnosti, keďže oblačnosť ako taká má najväčší vplyv na veľkosť intenzity toku žiarenia dopadajúceho na zemský povrch. Predpokladá sa, že pre krátke časové úseky je zmena oblačnosti spôsobená hlavne pohybom oblakov. Preto je algoritmus predpovede založený na výpočte vektorového pola pohybu oblakov. Vektorové pole sa získava zo satelitných snímok tak, že sa porovnávajú dva za sebou idúce snímky (moderné satelity poskytujú snímky s časovým krokom 30 minút a priestorovým rozlíšením 2,5 x 2,5 kilometra), na ktorých sa identifikuje skúmaný región. Získané vektorové pole sa následne aplikuje na predpoveď vývoja oblačnosti pre nasledujúci časový krok [1]. Z obrázku získaného predpoveďou sa odvodí hodnota intenzity toku žiarenia tak, že sa skombinuje informácia o odhadnutej priepustnosti atmosféry s hodnotami intenzity toku žiarenia pre bezoblačnú oblohu. Následne sa vyhodnotí presnosť predpovede. Platí, že čím je väčšia oblačnosť, tým predpoveď vykazuje väčšiu nepresnosť [2]. Na presnosť predpovede má taktiež vplyv uhol zenitu Slnka a charakter počasia, pretože rozličné počasie sa prejaví odlišnými hodnotami indexu oblačnosti, čo ovplyvní celý proces predpovede. Súčasným trendom je skrátenie časovej mierky predpovede. K tomu sa však už využívajú metódy založené na meraní intenzity toku dopadajúceho slnečného žiarenia priamo v mieste inštalácie fotovoltických elektrární, pretože časová dostupnosť satelitných snímok už nepostačuje pre tak krátke predpovede [3]. Veľa z týchto metód však využíva dáta, ktoré boli na danom mieste alebo v jeho okolí, merané už niekoľko rokov predtým [4], [5]. To si ale vyžaduje existenciu a prístup ku takýmto dátam.

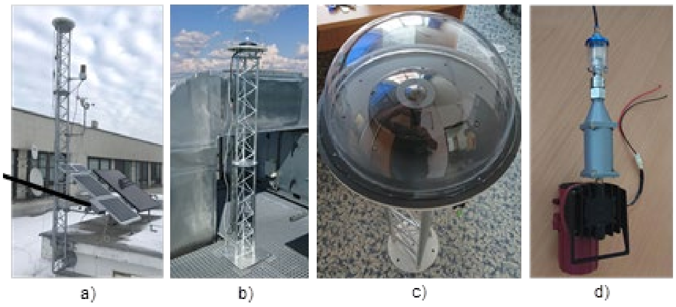
Ďalšou skupinou metód sú metódy, ktoré slúžia na odhad výkonu fotovoltickej elektrárne pre dlhšie časové mierky. Tie buď využívajú hodnoty toku intenzity slnečného žiarenia, ktoré sú štatisticky vypočítané pre reprezentatívny deň v rámci mesiaca [6], alebo využívajú výstupy z numerickej predpovede počasia, ktorá využíva zložité meteorologické modely atmosféry, ktoré umožňujú výpočet žiadaných meteorologických veličín ako napr. rýchlosť vetra, smer vetra, zrážky, tlak, teplotu a oblačnosť [7], [8]. Získané hodnoty je však potrebné prepočítať na menšie časové a priestorové rozlíšenie. Tieto metódy si vyžadujú veľmi výkonné počítače a rozsiahlu sieť meracích meteorologických staníc.

Automatické prístroje na určovanie miery oblačnosti už existujú, avšak nie sú ešte bežne rozšírené. Údaje ktoré poskytujú meteorologické stanice, napríklad na mapách s aktuálnym stavom počasia, sú zväčša určené priamo meteorológmi na meteorologických staniciach. Miera oblačnosti sa udáva v desatinách (prípadne osminách) pokrytia oblohy, kde 0/10, alebo 0/8, vyjadruje bezoblačnú oblohu, a 10/10, prípadne 8/8 úplne zamračenú oblohu. Táto hodnota sa určuje odhadom a nemusí byť presná; presnosť odhadu skúseného meteorológa na praktické účely postačuje. Jedným zo základných pilierov efektívnej a systematickej veľmi krátkodobej predpovede počasia je klasifikácia jednotlivých typov mračien. Svetová meteorologická organizácia (World Meteorological Organization - WMO) rozdeľuje jednotlivé typy mračien do 3 úrovní a 10 tried podľa tvaru, objemu, hrúbky a výšky mračien [8]. Avšak tieto komerčné riešenia, ktorých výstupom je miera oblačnosti, neposkytujú dostatočné informácie pre presnú veľmi krátkodobú predpoveď počasia. Z tohto dôvodu bude v rámci projektu riešená problematika sémantickej analýzy oblohy, ktorá bude zahŕňať sledovanie pohybu a evolúcie mračien, klasifikácie typu mračien, lokálny odhad tranzmisivity slnečného žiarenia a pod. Taktiež sa budú analyzovať ďalšie faktory, ktoré ovplyvňujú výslednú intenzitu dopadajúceho slnečného žiarenia akými sú napríklad prízemná hmla a mestský smog [9], [10].

II. TVORBA DATASETU PRE ANALÝZU OBLOHY

Za účelom obrazového snímania oblohy a vytvárania testovacieho datasetu (Obr. 1) boli využité dve IP kamery s možnosťou 360° (model GV-FER12203 od firmy GeoVision (Obr. 1c)). IP technológiou bol zabezpečený jednoduchý prenos dát po sieti a širokým zorným uhlom kamier vieme zaznamenať požadované snímky celej oblohy [11].

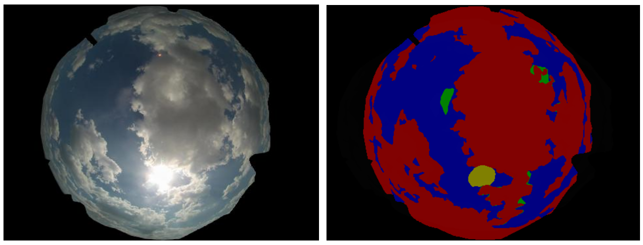
Primárny snímací systém bol umiestnený na pôde Žilinskej univerzity, konkrétne na strešnej časti katedry Multimédií a Informačno-Komunikačných Technológií (MIKT) (Obr. 2a) a sekundárny na streche Výskumného centra ŽU (Obr. 2b). Z dôvodu, aby kamera zaznamenávala čo najmenšiu časť okolitých budov a najväčšiu časť oblohy, bola umiestnená na vyvýšenú oceľovú konštrukciu. V rámci výskumu boli vytvorené nasledovné tri datasety, konkrétne CloudLabel4db, Dataset db9000 a DB-DATA-IMG. V tomto príspevku bude využitý dataset CloudLabel4db.



Obr.1 Prototyp kamerového systému, a) primárna snímacia platforma s fotovoltaickými panelmi a meteostanicami, b) sekundárna snímacia platforma pre zostavenie 3D mapy oblohy, c) kamera s kupolou, d) klimatizačná jednotka.

A. Dataset CloudLabel4db

Dataset CloudLabel4db slúži na klasifikáciu pixelov v obrázku. Každý pixel v obrázku má priradenú hodnotu triedy. Boli zvolené 4 triedy: slnko, oblačno, jasná obloha a polooblačno. Dataset obsahuje 75 obrázkov, pričom veľkosť obrázku je 3000 na 3000 pixelov, t.j. celkovo bolo klasifikovaných 675 000 000 pixelov. Príklad vytvoreného anotovaného datasetu je na Obr. 2. Priradenie farieb: žltá – slnko, modrá – jasná obloha, zelená – polooblačno, červená – oblačno.



a) b)

Obr. 2 Ukážka datasetu CloudLabel4db, a) originál, b) anotovaná vzorka.

III. NÁVRH ALGORITMOV PRE KLASIFIKÁCIU OBLOHY NA PIXELOVEJ ÚROVNI

Každý obraz bude klasifikovaný na pixelovej úrovni. To by malo poskytnúť zrozumiteľnejšie dáta pre ďalšiu analýzu. Taktiež sa aj značne zredukuje množstvo vstupnej informácie keď z 24 bitovej hodnoty RGB pixelu dostaneme iba 5 klasifikovaných hodnôt. Hodnoty budeme klasifikovať nasledujúcich tried: Slnko (Sun), Jasná obloha (Clear), Čiastočne zamračené (Partly cloudy), Zamračené (Cloudy) a ešte bola pridaná trieda Žiadna (None) pre pixely ktoré neobsahujú informácie o oblohe (čierna plocha na obraze, popr. strecha, stožiar a pod.).

V prvom kroku bolo nutné vytvoriť anotovaný dataset, čo je pri tomto type dát časovo veľmi náročné. Obrázky z datasetu sme rozdelili na 52 pre trénovanie a 23 na testovanie modelov. V nasledujúcich experimentoch bolo trénovanie nastavené na 300 iterácií (50 epoch), kedy vo väčšine prípadov sieť dosiahla svoje ustálené maximum a pri väčšom počte by mohlo dôjsť k pretrénovaniu. V dvoch prípadoch AlexNet a VGG to nepostačovalo, preto bol pri týchto sieťach po viacerých experimentoch nastavený počet iterácií na 1800 (300 epoch). Pre trénovanie bola ďalej použitá veľkosť 8 pre batch a SGDM optimizér pre výstupnú klasifikačnú vrstvu. Ukážka nastavenia trénovania je na Obr. 3.

```
options =

  TrainingOptionsSGDM with properties:

                    Momentum: 0.9000
            InitialLearnRate: 1.0000e-03
   LearnRateScheduleSettings: [1×1 struct]
            L2Regularization: 1.0000e-04
     GradientThresholdMethod: 'l2norm'
           GradientThreshold: Inf
                   MaxEpochs: 50
               MiniBatchSize: 8
                     Verbose: 1
            VerboseFrequency: 50
              ValidationData: []
         ValidationFrequency: 50
          ValidationPatience: Inf
                     Shuffle: 'once'
              CheckpointPath: ''
        ExecutionEnvironment: 'multi-gpu'
                  WorkerLoad: []
                   OutputFcn: []
                       Plots: 'training-progress'
              SequenceLength: 'longest'
        SequencePaddingValue: 0
    SequencePaddingDirection: 'right'
        DispatchInBackground: 0
     ResetInputNormalization: 1
```

Obr. 3 Ukážka nastavení trénovania modelu pre klasifikáciu pixelov

V nasledujúcich tabuľkách (Tab. I-Tab. VIII) sú výsledky experimentov na architektúrach AlexNet, VGG16, VGG19, ResNet18, ResNet50, Inception v2, Xception, Mobilent v2 vyjadrené prostredníctvom konfúznych matíc, kde hodnoty vyjadrujú počty klasifikovaných pixelov do jedntolivých tried. Tabuľky taktiež obsahujú vypočítané hodnoty P a R.

TABLE I. KONFÚZNA MATICA PRE TESTOVANIE MODELU ALEXNET

	Sun	**Clear**	**Cloudy**	**Partly Cloudy**	**None**	**P**
Sun	0	2804	2683	3	0	0,00
Clear	105	383522	125330	509	3786	0,75
Cloudy	45	138215	1460378	513	17182	0,90
Partly Cloudy	0	40491	35004	21	8	0,00
None	51	6112	31296	291	1726051	0,98
R	0,00	0,67	0,88	0,02	0,99	0,90

TABLE II. KONFÚZNA MATICA PRE TESTOVANIE MODELU SIETE VGG16

	Sun	**Clear**	**Cloudy**	**Partly Cloudy**	**None**	**P**
Sun	0	3670	1695	0	125	0,00
Clear	0	383769	106515	0	22968	0,75
Cloudy	0	147401	1458882	0	10050	0,90
Partly Cloudy	0	38600	35641	0	1283	0,00
None	0	29739	3705	0	1730357	0,98
R	0,00	0,64	0,91	0,00	0,98	0,90

TABLE III. KONFÚZNA MATICA PRE TESTOVANIE MODELU SIETE VGG19

	Sun	**Clear**	**Cloudy**	**Partly Cloudy**	**None**	**P**
Sun	0	4321	1120	0	49	0,00
Clear	0	402581	107158	0	3513	0,78
Cloudy	0	88622	1520722	0	6989	0,94
Partly Cloudy	0	37075	38443	0	6	0,00
None	0	22842	3966	0	1736993	0,98
R	0,00	0,72	0,91	0,00	0,99	0,92

TABLE IV. KONFÚZNA MATICA PRE TESTOVANIE MODELU RESNET18

	Sun	**Clear**	**Cloudy**	**Partly Cloudy**	**None**	**P**
Sun	3990	168	836	496	0	0,73
Clear	860	459006	31103	21203	1080	0,89
Cloudy	3029	69450	1502146	32986	8722	0,93
Partly Cloudy	36	24589	22287	28577	35	0,38
None	0	1895	8669	7	1753230	0,99
R	0,50	0,83	0,96	0,34	0,99	0,94

TABLE V. KONFÚZNA MATICA PRE TESTOVANIE MODELU RESNET50

	Sun	**Clear**	**Cloudy**	**Partly Cloudy**	**None**	**P**
Sun	3521	1197	772	0	0	0,64
Clear	532	474621	27734	9663	702	0,92
Cloudy	2019	67591	1520924	16474	9325	0,94
Partly Cloudy	0	28594	16849	30072	9	0,40
None	0	2109	9048	10	1752634	0,99
R	0,58	0,83	0,97	0,53	0,99	0,95

TABLE VI. KONFÚZNA MATICA PRE TESTOVANIE MODELU INCEPTION V2

	Sun	Clear	Cloudy	Partly Cloudy	None	P
Sun	3291	1390	791	18	0	0,60
Clear	256	453841	41684	16930	541	0,88
Cloudy	1874	47462	1539390	20742	6865	0,95
Partly Cloudy	40	19783	22658	33027	16	0,44
None	0	1180	6402	0	1756219	1,00
R	0,60	0,87	0,96	0,47	1,00	0,95

TABLE VII. KONFÚZNA MATICA PRE TESTOVANIE MODELU XCEPTION

	Sun	Clear	Cloudy	Partly Cloudy	None	P
Sun	4170	118	1202	0	0	0,76
Clear	1401	446833	45303	17697	2018	0,87
Cloudy	2300	71009	1498346	27598	17080	0,93
Partly Cloudy	304	29910	27138	18170	2	0,24
None	0	2375	13169	58	1748199	0,99
R	0,51	0,81	0,95	0,29	0,99	0,93

TABLE VIII. KONFÚZNA MATICA PRE TESTOVANIE SIETE MOBILENET V2

	Sun	Clear	Cloudy	Partly Cloudy	None	P
Sun	2457	1185	1763	85	0	0,45
Clear	289	450311	41520	19710	1422	0,88
Cloudy	1561	89691	1468932	44185	11964	0,91
Partly Cloudy	91	22998	24543	27880	12	0,37
None	0	2970	10024	62	1750745	0,99
R	0,56	0,79	0,95	0,30	0,99	0,93

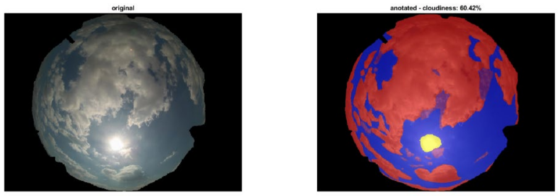
TABLE IX. CELKOVÉ POROVNANIE PRESNOSTI KLASIFIKÁCIE

	Alex Net	VGG 16	VGG 19	R_Net 18	R_Net 50	In_2	Xcep.	Mob v2
P	0,90	0,90	0,92	0,94	0,95	0,95	0,93	0,93
R	0,81	0,82	0,85	0,91	0,92	0,91	0,88	0,89
P2	0,83	0,83	0,87	0,90	0,92	0,92	0,89	0,88
R2	0,72	0,74	0,77	0,85	0,88	0,87	0,83	0,83
Ca	74,83	74,83	74,83	74,83	74,83	74,83	74,83	74,83
Cp	74,32	72,47	75,06	72,62	72,53	74,48	73,31	72,05

Pre názornejšie porovnanie boli výsledky spracované do Tab. IX, do ktorej sme k hodnotám P, R pridali hodnoty P2, R2, ktoré vyjadrujú presnosť a úplnosť pri zanedbaní triedy none, t.j. vyjadrujú hodnovernejšie presnosť a úplnosť klasifikácie pixelov, nakoľko trieda none mala vysokú presnosť a tiež vysokú početnosť pixelov v obraze, čo môže presnosť klasifikácie oblohy skresľovať. Ďalej tabuľka obsahuje hodnoty Ca a Cp. Ca vyjadruje percentuálnu oblačnosť oblohy v anotovanom obraze a Cp oblačnosť v klasifikovanom obraze príslušným modelom neurónovej siete. V tabuľke je uvedená priemerná oblačnosť celého testovacieho data setu. Na Obr. 4 je zobrazená ukážka anotácie obrazu na pixelovej úrovni. Na základe takejto anotácie boli modely trénované a následne vyhodnocované. Z každého obrazu bola taktiež vyrátaná percentuálna hodnota oblačnosti podľa nasledujúcej rovnice:

$$C = \frac{\sum Px_{Cloudy} + \frac{1}{2}\sum Px_{PartlyCloudy}}{\sum Px_{Sky}} * 100\% , \qquad (1)$$

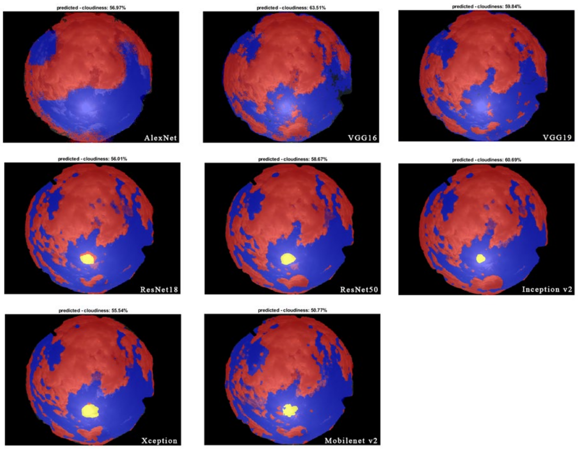
kde C je vypočítaná celková oblačnosť z obrazu, Px_{Cloudy} sú pixely, ktoré boli anotované alebo klasifikované do triedy cloudy, $Px_{PartlyCloudy}$ pixely patriace do triedy PartlyCloudy. Pixely tejto triedy boli do celkovej oblačnosti započítavané s pomerom jednej polovice, nakoľko vyjadruju polooblačno. Px_{Sky} vyjadruje všetky pixely oblohy, t.j. bez pixelov, ktoré vyjadrujú triedu none.



Obr. 4 Ukážka anotácie - originál a ručne anotovaný obraz, žltá – slnko, modrá – jasná obloha, bordová – čiastočne zamračené, červená – zamračené, čierna – žiadna.

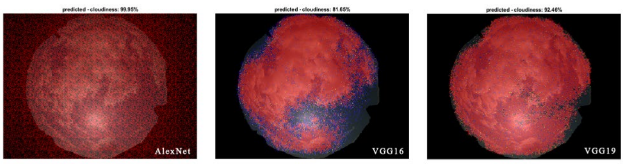
Ukážka klasifikácie jednotlivých modelov je zobrazená na Obr. 5. Ako je možné vidieť, niektoré modely zanedbali triedu Sun, nakoľko počet pixelov v obraze aj v celom datasete bol taký nízky, že to vo veľkej miere neovplyvnilo celkovú presnosť modelu. Pri následnej analýze oblohy by to však mohlo výrazne ovplyvniť výsledky, a preto je analýza výsledkov modelov a vizualizácia dôležitá, lebo napr. sieť AlexNet, ktorá dosiahla presnosť 90% a aj celková oblačnosť sa veľmi blízko priblížila tej anotovanej, dosiahla pre triedu Sun nulovú presnosť, čo vidieť aj na zobrazenej ukážke anotácie. Ako bolo spomenuté pri nastaveniach trénovania, niektoré architektúry potrebovali na trénovanie viac epoch, na Obr. 6 je zobrazená ukážka použitia modelov architektúr AlexNet a VGG po 50 epochách.

Z experimentov vyplýva, že segmentácia obrazu na pixelovej úrovni sa dokáže veľmi blízko priblížiť tej ľudskej, čo môže výrazne zlepšiť analýzu oblohy a následnú predikciu v stave oblohy v krátkych časových intervaloch. Taktiež je vidieť, že pri tejto úlohe nezávisí až tak veľmi na hĺbke modelu a počte jeho vnútorných parametrov, nakoľko experimenty ukázali, že jednoduchšie siete sa dokázali lepšie natrénovať.



Obr. 5 Ukážka klasifikácie vybraných architektúr CNN.

Najlepšie výsledky boli dosiahnuté na architektúrach ResNet50 (~25M parametrov) a Inception 2 (~25M), pričom architektúra VGG (~140M) také výsledky nedosiahla. Zaujímavý je aj fakt, že podobné výsledky boli dosiahnuté aj na architektúre Mobilenet v2, ktorá ma iba 3,5M parametrov, t.j. spracovanie takýchto dát je možné aj na jednoduchších zariadeniach.



Obr. 6 Testovanie architektúr Alexnet a VGG po 50 epochách.

IV. NÁVRH ALGORITMU PRE VEĽMI KRÁTKODOBÚ PREDPOVEĎ VÝKONU FOTOVOLTICKEJ ELEKTRÁRNE

Výsledky spracovania obrazových dát a následnej predikcie boli použité pre predikciu výkonu fotovoltických panelov [85]. Na základe celkovej účinnosti systému a poznania vstupných hodnôt bolo možné vypočítať výkon akejkoľvek fotovoltickej elektrárne. Do výpočtu však vstupovali rôzne chyby (dané vplyvom čiastočného zatienenia fotovoltických panelov, znečistením, zlým umiestnením, technickým stavom, atď.). Tieto chyby nie je možné presne zohľadniť a vyčísliť, teda predikovaný výkon FVE nikdy nebude úplne totožný so skutočným. Skrátením horizontu predikcie na 15 minút dopredu je však možné dosiahnuť jej vysokú presnosť.

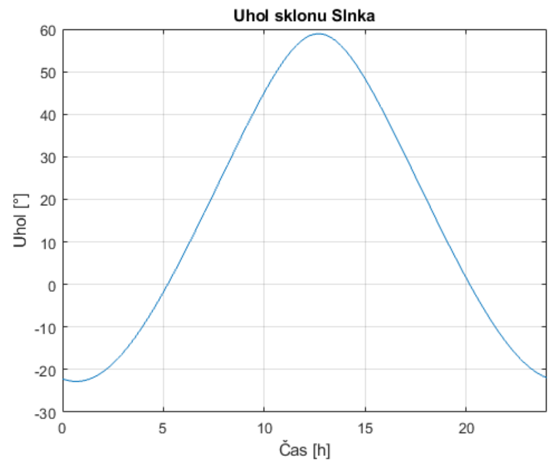
Aby bolo možné správne predikovať výkon fotovoltickej elektrárne (FVE), je potrebné do výpočtu zahrnúť nasledovné faktory vplývajúce na celkový generovaný výkon FVE:

- poloha Slnka voči FVE,
- uhol dopadu slnečného žiarenia na plochu fotovoltických panelov,
- intenzitu slnečného žiarenia,
- teplotu fotovoltických panelov.

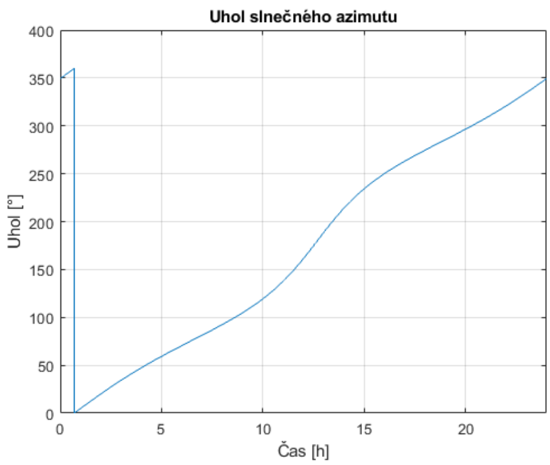
Výpočet polohy Slnka vychádza z astromických algoritmov, kde pohyby Zeme a planét sa zvyčajne počítajú v ekliptických súradniciach na základe roviny ekliptiky. Pre definované súradnice zemepisnej dĺžky a šírky, dňa a časového pásma je možné vypočítať polohu Slnka, vyjadrenú uhol slnečného azimutu a uhol sklonu Slnka počas definovaného dňa a zobraziť ich v podobe grafu. Pre polohu Výskumného centra UNIZA, kde je umiestnená testovacia FVE (zemepisná dĺžka = 49.200704; zemepisná šírka = 18.756425) a deň 12.5.2019 sú výsledky zobrazené na obrázkoch Obr. 7 a Obr. 8. Uhol dopadu slnečného žiarenia na plochu fotovoltických panelov je vlastne uhol medzi slnečnými lúčmi a vektorom kolmým na povrch panelov. V technickej praxi sa určuje jeho kosínus:

$$\cos\theta_i = \sin\theta_Z \cos\beta + \cos\theta_Z \sin\beta \cos(\gamma - \Phi_S), \quad (2)$$

kde β je uhol sklonu plochy FVE panelov a γ je uhol azimutu danej plochy.



Obr. 7 Uhol sklonu Slnka nad FVE Výskumného centra UNIZA pre deň 12.5.2019.



Obr. 8 Uhol slnečného azimutu pre deň 12.5.2019.

Slnečné žiarenie vo všeobecnosti rozdeľujeme na priame a difúzne. Priame žiarenie má určitý smer, ale difúzne žiarenie sa pohybuje akýmkoľvek spôsobom. Súčtom priameho a difúzneho žiarenia je potom globálne žiarenie. Pre estimáciu dopadu globálneho žiarenia na vodorovnú plochu sa používajú parametrické alebo dekompozičné modely. Parametrické modely si vyžadujú špecifické informácie o okolitých podmienkach (napr. znečistenie atmosféry, zložky slnečného žiarenia, oblačnosť, vlhkosť vzduchu, atď.). Dekompozičné modely sú založené na korelácii medzi difúznym a celkovým žiarením na horizontálnej ploche a definovaným koeficientom/indexom čistoty oblohy K_t.

Zvýšenie teploty má zásadný vplyv na panely FVE. Prejavuje sa to znížením výstupného napätia a tým znížením výstupného výkonu. Okrem toho má zvýšenie teploty negatívny vplyv aj na degradáciu samotných panelov, pretože vzrastom teploty sa zvyšuje namáhanie spojené s tepelnou rozťažnosťou panelov. Vo všeobecnosti platí, že pre každé zvýšenie teploty o 10 °C stúpne degradácia panelov asi dvakrát. Pre určenie teploty panelu FVE platí:

$$t_{FV} = t_{amb} + \frac{NOCT - 20}{800} . I_{G\beta}, \quad (3)$$

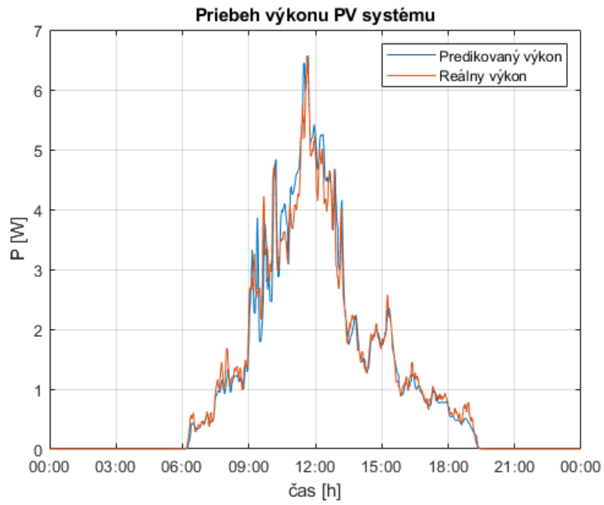
kde t_{anb} je teplota okolia a NOCT je nominálna prevádzková teplota článkov príslušného panelu. Výsledný výpočet predikovaného výkonu FVE P_{FVE} je súčinom plochy panelov FVE s_{FVE}, vypočítaného globálneho žiarenia na definovanú plochu $I_{G\beta}$, jednotlivých účinností (účinnosti panelov FVE vrátane degradácie η_{FVE}, teplotnej účinnosti panelov FVE η_{tFVE} a účinnosti striedača η_{INV}) a strát na kábloch Δ_k:

$$P_{FVE} = s_{FVE} . I_{G\beta} \frac{\eta_{FVE}}{100} . \eta_{tFVE} . \eta_{INV} . \Delta_k, \quad (4)$$

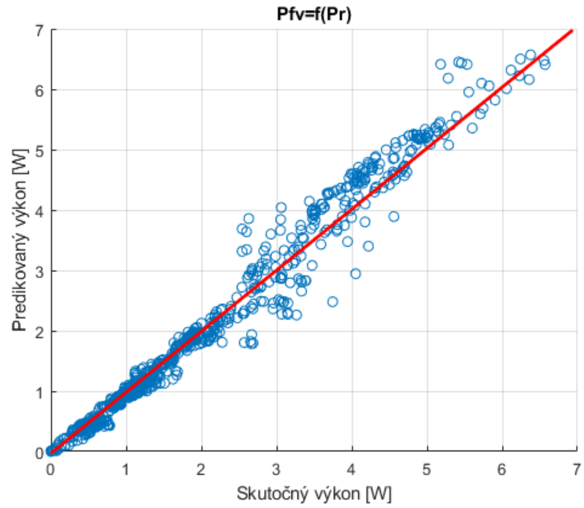
A. Vyhodnotenie presnosti simulačného modelu za účelom predpovede výkonu fotovoltickej elektrárne

Na základe celkovej účinnosti systému a poznania vstupných hodnôt je možné vypočítať výkon akejkoľvek fotovoltickej elektrárne. Do výpočtu však vstupujú rôzne chyby (dané vplyvom čiastočného zatienenia fotovoltických panelov, znečistením, zlým umiestnením, technickým stavom, ...). Tieto chyby nie je možné presne zohľadniť a vyčísliť, teda predikovaný výkon FVE nikdy nebude úplne totožný so skutočným. Skrátením horizontu predikcie na 15 minút dopredu je však možné dosiahnuť jej vysokú presnosť.

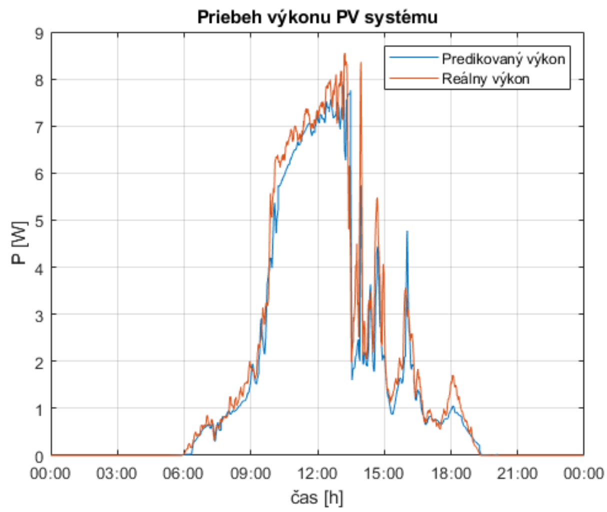
Na Obr. 9 - Obr. 12 sú zobrazené priebehy medzi skutočným a predpovedaným výkonom testovacieho fotovoltického panela pre deň s najlepšou a najhoršou predikciou. Pre oba dni sú uvedené aj hodnoty rozptylu, kde červená čiara predstavuje optimálny stav. Hodnota RMSE pre najhorší deň nadobudla hodnotu 0,25093. Na porovnanie, v deň s najlepšou predikciou mala RMSE hodnotu len 0,00389.



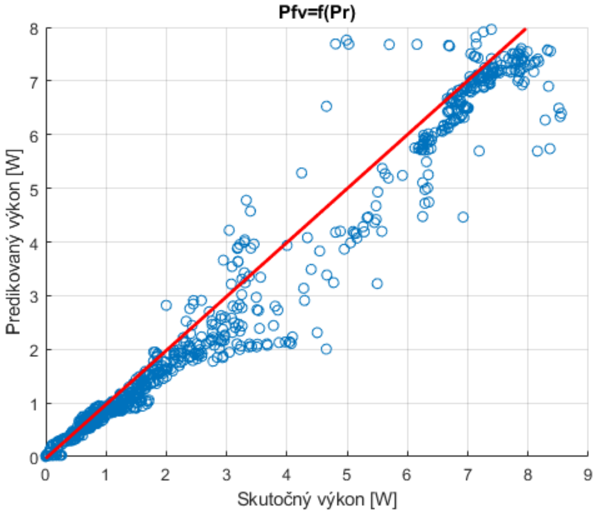
Obr. 9 Simulačný model jedného fotovoltaického panela pre deň s najlepšou predikciou.



Obr. 10 Priebehy predikovaného a skutočného výkonu testovacieho panela pre deň s najlepšou predikciou.



Obr. 11 Simulačný model jedného fotovoltaického panela pre deň s najhoršou predikciou.



Obr. 12 Priebehy predikovaného a skutočného výkonu testovacieho panela pre deň s najhoršou predikciou.

Na Obr. 9 - Obr. 12 sú zobrazené priebehy medzi skutočným a predpovedaným výkonom testovacieho fotovoltického panela pre deň s najlepšou a najhoršou predikciou. Pre oba dni sú uvedené aj hodnoty rozptylu, kde červená čiara predstavuje optimálny stav. Hodnota RMSE pre najhorší deň nadobudla hodnotu 0,25093. Na porovnanie, v deň s najlepšou predikciou mala RMSE hodnotu len 0,00389.

V. Záver

V danom príspevku bol navrhnutý predikčný algoritmus pre krátkodobú predpoveď výroby fotovoltickej elektrárne (FVE) napájajúcej inteligentnú budovu využitím neurónovej siete. Tento vytvorený systém musí vychádzať zo štatistického porovnania výstupov z kamerového systému sledujúceho oblohu v mieste inštalácie FVE a veľkosti vyrábaného výkonu vo FVE pri rôznych typoch počasia.

Navrhovaný predikčný systém umožní rozvoj nových prístupov riadenia výroby elektriny vo fotovoltických elektrárňach, ktoré sa tak svojimi regulačnými schopnosťami vyrovnajú resp. veľmi priblížia konvenčným zdrojom elektriny. To vytvorí priestor pre nové inovatívne riešenia v oblasti využívana FVE v rámci inteligentných budov, miest a regiónov, v ktorých budú FVE využívané pre napájanie rôznych typov spotreby elektriny, od malých domov a domácností až po veľké priemyselné, administratívne či obytné budovy. Na základe tejto analýzy sa v rámci našej budúcej práce bude zostavovať merací hardvér pre výpočet výkonu. Nasledujúcim cieľom je vyšpecifikovanie faktorov ovplyvňujúcich výkon fotovoltaickej elektrárne a odvodenie korekčných činiteľov, ktoré budú využité pri krátkodobej predikcii výkonu.

Poďakovanie

Táto publikácia vznikla vďaka podpore v rámci Operačného programu Integrovaná infraštruktúra pre projekt: Podpora výskumno-vývojových kapacít na poli generovania pokročilých softvérových nástrojov určených na zvýšenie odolnosti hospodárskych subjektov pred nadmernou volatilitou trhu s energetickými komoditami, kód ITMS2014+ 313011BUK9, spolufinancovaný zo zdrojov Európskeho fondu regionálneho rozvoja.

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Modeling and prediction of volatility based on GARCH model

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Abstract— **Market volatility is a fundamental characteristic of financial markets, reflecting the tendency of asset prices to fluctuate sharply and unpredictably over time. This paper provides an overview of market volatility, covering both theoretical and empirical perspectives, and highlighting some of the key debates and findings in the field. One of the most prominent theoretical frameworks for understanding market volatility is the Efficient Market Hypothesis (EMH), which posits that financial markets are always efficient in processing all available information, and that prices reflect all relevant information at any given time. According to this view, market volatility reflects the arrival of new information that is not yet incorporated into prices, leading to temporary fluctuations in asset prices. Next part of paper deals with GARCH model. It works by assuming that the volatility of an asset is dependent on its own past volatility. This means that if the volatility of an asset was high yesterday, it is more likely to be high today as well. The GARCH model also takes into account the volatility of the asset's returns, which is a measure of how much the asset's price has fluctuated in the past. The GARCH model can be used to estimate both historical and future volatility. Historical volatility is a measure of how much the price of an asset has fluctuated in the past. Future volatility is a measure of how much the price of an asset is expected to fluctuate in the future.**

Keywords— market volatility, efficient market hypothesis, market frictions, volatility clustering, prediction, GARCH model, value-at-risk (VaR)

I. INTRODUCTION

Market volatility is a fundamental characteristic of financial markets, reflecting the tendency of asset prices to fluctuate sharply and unpredictably over time. These fluctuations can be driven by a wide range of factors, including changes in economic conditions, shifts in investor sentiment, geopolitical events, and changes in monetary policy. The impact of market volatility can be felt across a range of asset classes, including stocks, bonds, currencies, and commodities, and can have significant implications for investors, traders, and businesses [1].

The study of market volatility has been the subject of intensive research and analysis, with numerous theoretical and empirical approaches developed over the years. This paper provides an overview of the literature on market volatility, covering both theoretical and empirical perspectives, and highlighting some of the key debates and findings in the field [1].

One of the most prominent theoretical frameworks for understanding market volatility is the Efficient Market Hypothesis (EMH), which posits that financial markets are always efficient in processing all available information, and that prices reflect all relevant information at any given time. According to this view, market volatility reflects the arrival of new information that is not yet incorporated into prices, leading to temporary fluctuations in asset prices. While the EMH has been subject to extensive criticism and debate, it remains a key reference point for many discussions of market volatility [3] .

Another important theoretical perspective on market volatility is the concept of market frictions, which refers to the presence of barriers to the efficient functioning of financial markets. Market frictions can take many forms, including transaction costs, taxes, and information asymmetries, and can lead to persistent deviations of asset prices from their fundamental values. This can contribute to prolonged periods of market volatility, as investors struggle to discern the true underlying value of assets [1-3].

Empirical studies of market volatility have employed a wide range of methods and techniques, including statistical analysis, econometric modeling, and machine learning. These studies have produced a wealth of insights into the nature and determinants of market volatility, including the role of macroeconomic variables, investor sentiment, and financial market structure [4].

One important finding from the empirical literature is the existence of persistent and recurring patterns in market volatility over time. For example, many studies have documented the presence of volatility clustering, whereby periods of high volatility tend to be followed by further periods of high volatility. Other studies have identified the presence of long-term trends in volatility, with some asset classes exhibiting a tendency towards increased or decreased volatility over extended periods of time [4-5].

The impact of market volatility can be felt across a range of financial assets, with stocks, bonds, currencies, and commodities all subject to significant price swings during periods of market turbulence. Moreover, the implications of market volatility can extend beyond financial markets, with high levels of volatility often associated with broader economic and geopolitical uncertainty [6].

To better understand market volatility and its impact, researchers and practitioners have developed a range of tools and techniques. These include measures of volatility such as the VIX index, which tracks the implied volatility of options on the S&P 500 index, and quantitative models such as the Black-Scholes model, which can be used to price options and other derivatives. Risk management techniques such as value-at-risk (VaR) can also be used to assess and manage exposure to market volatility.

Despite these tools and techniques, market volatility remains a complex and dynamic phenomenon that can be challenging to predict and manage. Moreover, the impact of market volatility can vary depending on the specific asset class or financial instrument in question, as well as the broader economic and geopolitical context. As such, it is important for investors and traders to remain vigilant and adaptive when navigating periods of market volatility [2-8].

In conclusion, market volatility is a key feature of financial markets that can have significant implications for investors, traders, and businesses. While market volatility can create opportunities for those who are able to navigate it effectively, it can also pose challenges and risks for those who are unprepared. As such, it is important for investors and traders to remain informed and vigilant when navigating periods of market volatility, and to use a range of tools and techniques to manage their exposure to price fluctuations and other forms of market risk.

II. VKOSPI PREDICTION USING GARCH MODEL

In an era of uncertainty, market volatility has never been higher. The VIX, also known as the "fear index", reached a record high during COVID-19. Predicting tomorrow's volatility is the key to future investments [9-14].

Meanwhile, the machine learning boom is spreading across industries from automotive to retail. Machine learning solutions are revolutionary; in other words, they have little respect for conventional ways of doing things. This rigidity can be a disadvantage in some cases [10].

The goal of this paper is to predict market volatility. Instead of machine learning, it is integrated with a good old econometric (statistical) model. Data from the Korean stock market from 2009 to 2019 were used. The target data is the VKOSPI, which represents the volatility of the Korean stock market.

A. Options

Options are financial instruments that are derivatives based on the value of underlying securities, such as shares. An option contract offers the buyer the option to buy or sell - depending on the type of contract they hold - the underlying asset. Unlike futures, the holder is not obliged to buy or sell the asset if it chooses to do [11].

Call options allow the holder to buy an asset at a set price within a certain time frame.

Put options allow the holder to sell an asset at a specified price within a specified time frame.

Each option contract has a specified expiry date by which the holder must exercise the option.

B. Volatility

In finance, volatility (symbol σ) is the degree of fluctuation of a series of trading prices over time, usually measured by the standard deviation of logarithmic returns. Historical volatility measures the time series of past market prices. Implied volatility looks into the future and is derived from the market price of a market-traded derivative (especially an option).

C. Volatility σ

The stock is a measure of our uncertainty about the returns that the stock provides. It can be defined as the standard deviation of the return provided by a stock. Volatility can be measured in several ways [11]. Historical volatility is calculated from historical stock price data. Implied volatility is calculated from option prices observed in the market. VKOSPI indicates implied volatility

III. GARCH MODEL

The GARCH model has been extended in a number of ways to capture a wider range of stylized facts in financial time series. Some of the most common extensions include [9-14]:

- Leverage effects: The leverage effect is the tendency for volatility to increase following negative returns. This can be captured by using asymmetric GARCH models, such as the EGARCH and GJR-GARCH models.
- Long-range dependence: Long-range dependence is the tendency for volatility to be correlated over long time horizons. This can be captured by using fractional integrated GARCH (FIGARCH) models.
- Regime switching: Regime switching GARCH models allow the parameters of the GARCH model to vary over time. This can be useful for modeling periods of high and low volatility.
- Multivariate GARCH models: Multivariate GARCH models can be used to model the volatility of multiple asset returns simultaneously. This can be useful for portfolio optimization and risk management.

These extensions have made the GARCH model even more powerful for modeling and forecasting volatility in financial markets. They are widely used by practitioners and researchers alike.

In addition to the above extensions, the GARCH model has also been used to model and forecast volatility in other areas, such as energy markets, commodity markets, and macroeconomic markets.

Examples of how the GARCH model has been used in practice:

- Trading strategies: The GARCH model can be used to develop volatility-based trading strategies. For example, a trader could use the GARCH model to forecast future volatility and then buy options when volatility is low and sell options when volatility is high.
- Risk management: The GARCH model can be used to assess risk, such as Value-at-Risk (VaR). VaR is a measure of the maximum loss that a portfolio is expected to suffer over a given time horizon with a given probability. The GARCH model can be used to estimate the volatility of a portfolio's returns, which is an important input into the VaR calculation.
- Portfolio optimization: The GARCH model can be used to optimize portfolios. For example, an investor could use the GARCH model to estimate the volatility of different assets and then construct a portfolio that minimizes volatility while maximizing expected return[9-14].

A. *Methodology*

Consider the time series of returns $rt = \mu + \varepsilon_t$, where μ is the expected return and εt is white noise with zero mean. Despite serial correlation, the ε_t series may not be serially independent. For example, it can represent conditional heteroskedasticity.

The generalized autoregressive conditional heteroscedasticity (GARCH) model assumes a specific parametric form for this conditional heteroscedasticity. More precisely, we say that $\varepsilon t \sim GARCH$ if we can write $\varepsilon t = \sigma_t z_t$ where z_t is the standard Gaussian (Eq.1):

$$\sigma_t^2 = \omega + \alpha\varepsilon_t^2 - 1 + \beta\sigma_{t-1}^2 \quad (1)$$

B. *Estimate*

V-Lab estimates all parameters (μ,ω,α,β) simultaneously by maximizing the log likelihood. The assumption that z_t is Gaussian does not mean that the returns are Gaussian. Although their conditional distribution is Gaussian, it can be shown that their unconditional distribution represents excessive kurtosis (fat tails). In fact, the assumption that the conditional distribution is Gaussian is not as restrictive as it seems: even if the true distribution is different, the so-called quasi-maximum likelihood (QML) estimator is still consistent under fairly mild regularity conditions.

In addition to leptokurtic returns, GARCH the model captures other stylized facts in financial time series, such as volatility clustering. Volatility is likely to be higher at time t if it was also high at time t-1. Another way to see this is to note that the shock at time t-1 it also affects the variance in time. However, if α+β<1, the volatility itself is mean reverting and fluctuates around σ, the square root of the unconditional variance (Eq. 2):

$$\sigma^2 := Var(r_t) = \frac{\omega_1}{1-\alpha-\beta} \quad (2)$$

C. *Prediction*

Let $r_T$be the last observation in the sample and let $\hat{\omega}, \hat{\alpha}$ and$\hat{\beta}$ are the QML estimates of the parameters ω, α , and β , respectively It follows from the GARCH model that the forecast of the conditional variance at time $T + h$ is (Eq. 3):

$$\hat{\sigma}_{T+h}^2 = \hat{\omega} + (\hat{\alpha} + \hat{\beta})\hat{\sigma}_{T+h-1}^2 \quad (3)$$

and so by iteratively applying the above formula we can predict the conditional variance for any horizon h . Then the prediction of the volatility of the compound is at time $T + h$ (Eq. 4)

$$\hat{\sigma}_{T+1:T+h} = \sqrt{\sum_{i=1}^{h} \hat{\sigma}_{T+i}^2} \quad (4)$$

Note that for large *h,* this composite volatility forecast converges to (Eq. 5):

$$\sqrt{h}\sqrt{\frac{\hat{\omega}}{1-\hat{\alpha}-\hat{\beta}}} \quad (5)$$

scaling over the forecast horizon using the well-known square-root law, times the GARCH-implied unconditional volatility estimate model

D. *Estimate historical volatility using the GARCH model*

GARCH or more precisely GARCH(1,1) is an econometric model widely used to estimate historical volatility.

GARCH estimates historical volatility on day *n* with:

Rate of return (of the underlying asset) on day *n-1* (denoted by *u*)

Volatility on day *n-1* (denoted by σ)

Note that σ^2 is often referred to as variance

There are three coefficients in the model:

- alpha, coefficient u^2
- beta, coefficient σ^2
- omega, constant (It's actually not just a constant, but we'll keep it simple here.)

The formula for estimating (historical) volatility on day *n* is (Eq.6):

$$\sigma_n^2 = \omega + \alpha u_{n-1}^2 + \beta\sigma_{n-1}^2 \quad (6)$$

Calculate the return

The formula for return is as follows, where *u* indicates return and *S* indicates the price of the underlying asset (eg. shares). There is another formula that involves the logarithm, but this one will be used here (Eq. 7).

$$u_n = (S_n - S_{n-1})/S_{n-1} \quad (7)$$

Select coefficient values in the model - Optimize

It was used the scipy.optimize library to optimize the function we created earlier.

The NYU V-Lab estimate (February 15, 2020) was used for the initial estimate. The reason for not simply taking the V-Lab estimate is that the ideal coefficients can vary over time. The bounds are set as a result of the basic concept of GARCH, which will not be explained further here.

E. Select values for coefficients in the model - Build function¶

To estimate the volatility using the model, it is necessary to choose values for the coefficients. This is done with historical data using the "maximum likelihood method". This method involves maximizing the probability of occurrence of historical data. The return on any day n (u_n) is assumed to follow a normal distribution with zero mean. The variance in each day is v_n . So the probability of observing u_n is (Eq. 8):

$$\frac{1}{\sqrt{2\,\pi v_n}}\exp(\frac{-u_i^2}{2v_n}) \tag{8}$$

Taking logarithms and ignoring constant multiplying factors, the expression we want to maximize each day is the following (Eq. 9).

$$-ln(v_n) - (\frac{u_n^2}{v_n}) \tag{9}$$

The sum of the above expression over the data is what we ultimately want to maximize.

Return(u_n) values are calculated directly from the data. (This was done in 2-1.)

The variance (v_n) was estimated by GARCH. The initial variance is set from the actual VKOSPI value on that date.

The variance (σ^2) represents 1 day. VKSOPI is the volatility index (σ) for 1 year expressed in percentage (%). Assuming that there are 252 trading days per year, the VKOSPI can be converted to variance as follows (Eq. 10):

$$Variance = (VKOSPI)^2/(252 \cdot 100) \tag{10}$$

Since the optimization takes a lot of time, the result is already loaded and you can load it.

Table 1: Results of optimization

Optimization result		Errors	
alpha	0.0451	**Test (0)**	**Test (516)**
beta	0.9379	MAE: 2.0174	MAE: 1.3302
omega	1.4843e-06	RMSE: 2.9151	RMSE: 1.9950

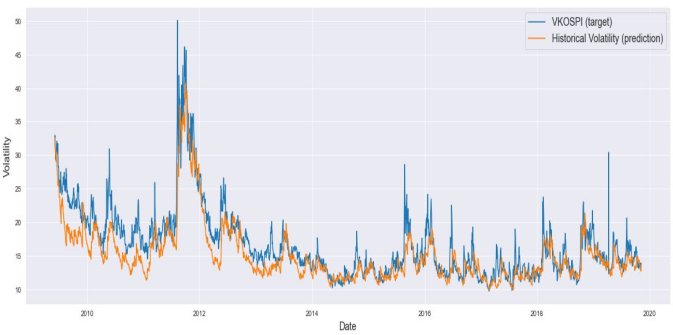

Fig. 1 Graphical representation of results

In Table 1, there are results of optimization using the GARCH model and calculation errors. In figure 1, there is a graph of predicted values with a comparison with historical data.

The results of predicting volatility using the GARCH model are generally positive. The model has been shown to be effective in forecasting volatility over a range of time horizons. While the GARCH model has been shown to be effective in predicting volatility, it is important to note that it is not a perfect model. Like any statistical model, the GARCH model is subject to sampling error. This means that the model's predictions will not always be accurate. Additionally, the GARCH model is based on historical data. This means that the model may not be able to accurately predict volatility in the future if there are significant changes in the underlying market conditions.

IV. Conclusion

Market volatility is a key feature of financial markets that can have significant implications for investors, traders, and businesses. While market volatility can create opportunities for those who are able to navigate it effectively, it can also pose challenges and risks for those who are unprepared. As such, it is important for investors and traders to remain informed and vigilant when navigating periods of market volatility, and to use a range of tools and techniques to manage their exposure to price fluctuations and other forms of market risk.

The GARCH model is a powerful tool for estimating and forecasting volatility in financial markets. It has been shown to be effective in a wide range of empirical studies, and it is widely used by practitioners in the financial industry. However, it is important to note that the GARCH model is just one of many models that can be used to estimate and forecast volatility. Other models, such as the exponential GARCH (EGARCH) model and the stochastic volatility (SV) model, may be more appropriate for certain applications. It is also important to note that the GARCH model is a statistical model, and it is subject to all of the usual caveats associated with statistical models. For example, the GARCH model is only as good as the data that it is trained on. If the data is noisy or incomplete, the GARCH model may not produce accurate results.

Overall, the GARCH model is a valuable tool for investors and traders to use in managing their risk exposure. However, it is important to use the model with caution and to be aware of its limitations.

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The Principles of Electricity Market Operation

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***Abstract*— This paper introduces basic concepts of electricity market operation. The article defines possible market participants, types of electricity markets as well as process of settlement of an organized market. As a result, the paper provides a comprehensive view of the principles of electricity market operation that can help market participants understand better the latest changes and price volatility in European electricity markets.**

***Keywords* — electricity market; market model; trading; pricing**

I. Introduction

The electricity market can be defined as a centralized mechanism through which participants can transparently exchange electricity at a price they are willing to pay or accept, depending on the capacity of the electrical grid. The electricity market is a general concept that encompasses a set of various types of markets where electricity and various ancillary services are traded. Ancillary services include power and frequency regulation, voltage regulation, and other services.

The electricity market operates within clearly defined boundaries. These boundaries are generally defined for a large region bounded by its electrical network. In most cases, the boundary of the electrical network within which the power system operates also defines the boundary for the specific electricity market. From an economic perspective, a clear definition of the market boundary is extremely important because this defined boundary determines which elements or participants will or will not be part of a specific market.

In general, the electricity market can be divided into two different types:

- Energy market,
- Capacity market.

Both markets complement and are closely related to each other. This classification arises from the same concepts used in the field of energy systems. The capacity of a generation source is the maximum ability of the source to deliver energy to the power system. The actual energy produced in real-time operation by this source may or may not reach the level of its maximum capacity. Therefore, the energy market pertains to the actual energy produced by participating generation sources, while the capacity market relates to the availability of the maximum capacity of those sources. This difference is crucial in understanding these two different markets. Some market designs include only the energy market and are called energy-only markets (EOM). Some other designs include both energy and capacity markets, and these are referred to as energy-capacity markets.

The energy market provides a platform and mechanism for matching energy demand with supply while considering technical constraints. The energy market is usually short-term, such as day-ahead markets, real-time markets, or hourly markets. Settlement of the energy market for a longer time horizon, such as a week ahead, is very challenging because it requires forecasts of load and future supply from both generators and consumers, which are uncertain. Energy markets provide settlement market prices that serve as the basis for determining revenues for generators.

Among energy markets, day-ahead markets and real-time balancing markets are predominant. Most electricity markets in the United States and European countries have day-ahead markets as well as real-time markets, although the settlement mechanisms for real-time markets may vary. Some electricity markets also have intra-day energy markets where markets settle an hour or half an hour ahead. In general, the day-ahead market is a forward market, while the real-time market is a spot market. However, the day-ahead market can sometimes be considered part of the spot market. As a complement to the energy market, the capacity market is designed to provide additional revenues to generators that may not have sufficient revenues from energy markets alone. Not all existing electricity markets have capacity markets, and not all capacity markets have the same characteristics.

One of the goals of the market pricing scheme is to provide participants in the market with both short-term and long-term price signals so that they can make appropriate economic decisions in the market environment. Short-term price signals are typically provided by prices in day-ahead markets, intra-day markets, and real-time markets. Long-term price signals are provided by the long-term capacity auction market or, in some cases, a term electricity market. In general, energy capacity markets are better at providing longer-term price signals than energy-only markets. These prices reflect the results of a complex combination of economic decisions made by market participants through offers based on expected and actual system network topology [1] - [5].

II. Participants in the Electricity Market

A. Producers

An electricity producer is a natural or legal person authorized to generate electricity under energy law. Producers include power plant operators and operators of renewable generation facilities. The energy equipment of electricity producers must be connected to the transmission or distribution system. These producers can then decide to sell the generated electricity directly to large consumers, such as large industrial companies or distribution companies. Another option for producers is to sell the generated electricity on the exchange. Although this method is referred to as "direct sales," only a small number of power plant operators personally sell electricity on the exchange. Often, they entrust this task to an "electricity trader" who sells electricity on behalf of the producers for a commission [4], [6], [7].

B. Transmission System Operators

A Transmission System Operator (TSO) is a legal entity authorized to transmit electrical energy within a defined area according to energy law. The TSO ensures the transmission of electrical energy, reliable operation, and development of the transmission system. The TSO is also responsible for the power balance within the entire regulatory area. Transmission systems are used for nationwide and cross-border transportation of large volumes of electricity through electrical lines operated at extra-high voltages. They connect the high-voltage networks operated by distribution system operators or directly to significant electricity consumers [4], [6], [7].

C. Distribution System Operators

A Distribution System Operator (DSO) is a legal entity authorized to distribute electricity within specific delimited areas. DSOs ensure the reliable operation and development of the distribution system within the licensed area. Often, these are public services that operate regional high and low-voltage networks used to supply end consumers with electricity. DSOs manage the flow of electricity in the distribution system while respecting the transmission of electricity between other distribution systems and the transmission system, in cooperation with operators of other distribution systems and the transmission system operator [4], [6], [7].

D. Suppliers

An electricity supplier is a natural or legal person authorized to supply electricity. Supplying electricity means selling electricity to end consumers [4], [6], [7].

E. Consumers

An electricity consumer can be an electricity trader or an end electricity consumer. An end electricity consumer is a consumer of electricity in households or a consumer of electricity outside of households. An electricity consumer in households is a natural person who purchases electricity for their own household consumption. An electricity consumer outside households is a natural or legal person who purchases electricity not used for their own household consumption. An eligible consumer is a natural or legal person authorized to choose their electricity supplier. Eligible consumers have the right to select their electricity supplier. Eligible consumers are divided into [4], [6], [7]:

- with transferred responsibility for deviation - they purchase electrical energy through a third party who pays all fees and assumes all risks on their behalf,
- with their own responsibility for deviation - they purchase electricity independently and have a contract for balancing deviations with the entity settling payments.

F. Electricity Traders

An electricity trader is a natural or legal person who buys electricity for the purpose of further resale. Traders buy electricity on the domestic or foreign market and sell it to other participants in the electricity market. They essentially act as both suppliers and consumers of electricity [4], [6], [7].

G. Aggregator

An aggregator is a legal entity authorized to supply electricity and engage in aggregation activities. An independent aggregator is an aggregator that uses the flexibility of electricity consumption, supply, or generation at the point of consumption or delivery provided by a flexibility provider while not assuming responsibility for deviations caused by electricity delivery or consumption when flexibility is not activated [7].

H. Operator of Electricity Storage Facilities

An operator of electricity storage facilities is a natural or legal person who stores electricity in an electricity storage facility. Electricity stored in this way can be used for personal consumption or supplied and withdrawn from the transmission or distribution system under an access agreement [7].

I. Energy Community

An energy community is a legal entity established for the purpose of electricity generation, supply, electricity sharing, electricity storage, aggregation activities, electricity distribution, operation of charging stations, or the provision of other services related to meeting the energy needs of its members or shareholders in order to achieve environmental, economic, or social community benefits. However, such a community cannot conduct its activities for profit [7].

J. Short-Term Electricity Market Organizer

A short-term electricity market organizer is responsible for organizing and evaluating the short-term cross-border electricity market within a defined area, settling deviations, and performing related activities such as data measurement and centralized billing according to market rules. The short-term electricity market organizer is obliged to enter into deviation settlement agreements with deviation settlement entities and allow any deviation settlement entity that meets the market organizer's commercial conditions and has entered into access and participation terms for the organized cross-border market to trade on the organized cross-border market [7].

III. ENERGY MARKET MODELS

There are many possible ways or schemes currently used for trading and contracting electrical energy between sellers and buyers. The most common forms of electricity trading include bilateral contracts, the energy pool model, the energy exchange model, or various combinations thereof.

Bilateral contracts are based on negotiations that take place directly between the parties involved without a central exchange. Bilateral contracts are known as over-the-counter or non-organized markets because contractual parties must agree on transaction terms among themselves without the support of any central entity.

The energy pool model, energy exchange model, and later ISO models are known as organized markets since these markets are cleared by a central market clearing entity. In such markets, both sellers and buyers submit bids to the central market clearing entity. This central entity then compares the offers from producers with those from consumers and determines the final winning sellers with winning schedules using an auction mechanism. The prevailing market form used in these market clearing mechanisms is the "single price market." Market prices are subsequently determined from these auctions.

These organized markets are structured markets where trading procedures and structural conditions of operation are defined based on defined market rules. The set of forward and spot market prices published by organized markets serves as an important reference for financial and bilateral transactions taking place in parallel markets. Organized and non-organized markets complement each other. The entity responsible for managing organized markets in the energy pool model or energy exchange model is called an electricity market operator. The primary functions of the market operator are to ensure and promote market competitiveness and to conduct financial settlements for completed transactions. A market operator, when supplemented by energy regulators, should ensure the integrity and proper governance of the electricity market [1], [2], [4], [5].

IV. SETTLEMENT OF THE ORGANIZED MARKETS

Economic theory suggests that in a free market, there will be a single price that brings supply and demand into equilibrium. This price is called the equilibrium price. Buyers need to acquire limited resources or commodities possessed by sellers, which creates a strong incentive for them to engage in trade. In its simplest form, continuous interaction between buyers and sellers allows the price to be determined over time. The equilibrium price in market settlement is also known as the market clearing price because at this price, consumers purchase the exact amount that producers bring to the market, leaving no surplus. This is efficient because there is neither excess supply nor wastage of resources, nor is there a shortage. In this case, the market is efficiently cleared. This is a central feature of the price mechanism and one of its significant advantages. For markets to function, efficient information flow between buyers and sellers is essential.

In most electrical grids, demand and supply must be immediately balanced because storing electricity is very challenging and costly. As a result, transmission constraints and their management in the market environment often have a significant impact on market prices. In the electricity market, the market clearing price is the price that balances demand and supply, just like in other commodity markets. The market settlement process for the electricity market can be described as an optimization problem.

The real-time electricity market is settled using the Security Constrained Economic Dispatch (SCED) algorithm. The goal of SCED is to solve an optimization problem whose task is to minimize the total production costs while maintaining system reliability, subject to various system constraints. The results of SCED include the required output levels of resources and market prices, either for a zone or several nodes in the system. The required output levels of resources are production schedules in MW, and market prices are determined in €/MWh.

In general, two main pricing mechanisms are used in any electricity market: zonal pricing and nodal pricing.

A. Zonal Pricing

For most current electricity markets, zonal pricing was the first pricing mechanism adopted to address network capacity issues. In zonal pricing, the market price is uniform within a specific zone, regardless of the possibility of congestion within the zone. If there is more than one zone, inter-zonal transmission constraints are generally considered, which can lead to different prices in different zones, depending on the severity of these constraints. A zone can be a large regulatory area, state, or country. This zonal pricing proposal aimed to minimize the complexity of market price settlement associated with nodal pricing. It is also politically more acceptable with a single price within a state or country. These are the main reasons why electricity markets in most European countries still use zonal pricing schemes [1], [21], [8]-[11].

B. Nodal Pricing

Nodal pricing, also referred to as locational marginal pricing (LMP), is more complex and computationally intensive than zonal pricing. This type of pricing is more intricate because it uses a pricing scheme known as local marginal price (LMP), where electricity prices are determined on a marginal basis at the node level of the power system. This pricing scheme involves tradable transmission rights and introduces trading rules specifying the compensation for transmission losses needed to transfer energy. The difference in spot prices between any two locations corresponds to the transmission cost between the two nodes. Since electrical networks are represented by nonlinear alternating current network models, the model is typically simplified by linearizing the network using a direct current optimal power flow (DCOPF) approach, which incorporates technical parameters related to transmission constraints and losses during transmission.

Within nodal pricing, the local marginal price generally consists of three components: the system marginal energy cost (SMP), marginal congestion cost (MCC), and marginal loss cost (MLC). In this case, LMP at the selected market hub represents SMP. In the standard decomposition approach, the choice of the market hub is also important, as selecting two different reference hubs could yield two different results for each component of the standard LMP. However, the final LMP would be the same regardless of which node was chosen as the reference hub [1], [11], [8]-[13].

V. TYPES OF ELECTRICITY MARKETS

One of the primary objectives of the electricity market is to facilitate the economic functioning of the power system while ensuring safe and reliable network operation. Alongside secure network operation, one of the main roles of the electricity market is to calculate market prices that provide economic signals for the development of power generation facilities or industrial loads, optimize the utilization of generation capacity, and foster the development of renewable energy sources.

Market rules for the electricity market need to be established to ensure fair network access and promote efficient investments in the market, assuming they will reduce electricity costs. One of the unique aspects of electricity markets compared to other commodity markets is that electricity must be generated, distributed, and delivered in real-time. Therefore, while the primary goal of the electricity market is to calculate market prices, its complexity lies in operating the power system in real-time. It is important to note that secure operation must be ensured at all times, regardless of how the market functions, as system security is the most critical aspect of network operation.

Energy markets, in general, encompass the day-ahead market, real-time market, and intra-day markets. Most markets today are dominated by day-ahead and real-time markets, with only a few having intra-day markets [1], [4].

A. Forward Market

A significant portion of electricity is sold before it is generated. Bilateral contracts in the forward market are signed months, quarters, or even years in advance. Electricity suppliers, large consumers, and power plant operators hope this will facilitate cost and revenue forecasting. Due to dynamic pricing, practically every megawatt-hour of electricity is traded back and forth multiple times before finally being sold to the consumer. These transactions are predominantly over-the-counter trades and do not conflict with the energy-only trading model[14].

B. Day-Ahead Market

Among energy markets, the day-ahead energy market is one of the most critical markets. The day-ahead market is a forward market, sometimes categorized as an intra-day market, where hourly settlement prices, either zonal or nodal, are calculated for each zone or node in the system for every hour of the following operating day. The calculation of market settlement prices is based on production bids, demand bids, virtual bids in some markets, and schedules of bilateral transactions submitted to the day-ahead market. Depending on market price-setting rules, various types of bids may exist. Common types include simple bids, block bids, or complex bids.

The day-ahead market can be complemented by several intra-day markets, such as the hourly-ahead market, where each participant can adjust their open positions closer to real-time. Participants can reduce their imbalanced risks to avoid imbalance charges, which can subsequently help reduce the required ancillary services for grid operators. Some markets allow re-bidding for participants not selected in the day-ahead market, enabling them to re-evaluate their bids for potential participation in the real-time market.

The integrated day-ahead market simultaneously analyzes energy and ancillary service markets to determine if there are congestions in the transmission network and confirms the reserves needed to balance supply and demand based on actual supply and demand. The system ensures that the sum of generation and imports equals the sum of load, exports, and losses in transmission. It also ensures that the final schedules are feasible considering network-wide modeling constraints. When the assumed load is not met in the integrated day-ahead market, the process allows the market operator to procure additional capacity by identifying available resources with the lowest costs that were not previously committed [1], [14], [15].

C. Real-Time Market

In general, the real-time energy market is a balancing market where market settlement prices are calculated in fixed time intervals using an economic dispatch algorithm based on the actual state of the system. The current operational state of the system is typically provided by the energy management system, which includes state estimation supported by data from each node in the energy system. Unlike the day-ahead market, there are no pre-arranged trades or contractual energy prices among participants in the real-time market. The most critical parameter is maintaining energy balance within the network. Consumers or producers do not have time to seek favorable prices but simply observe calculated prices set by the market operator at fixed intervals. Consequently, real-time deviations from contracted quantities in the day-ahead or intra-day markets become real-time market trades.

Regarding market design, the energy fund model approach is superior in addressing supply and demand balance and real-time market settlement compared to the energy exchange model.

In European markets, the balancing market is organized by the transmission system operator, where participants with available generators and loads submit bids for balancing. With balancing bids, participants offer to increase or decrease their electricity generation or consumption for a specific operating hour [1], [4].

D. Two-Settlement Market

The existence of day-ahead and real-time markets has given rise to the concept known as the "two-settlement system." The two-settlement market consists of two separate markets: the day-ahead market and the real-time market. Each market has its own settlement. Day-ahead market settlement is based on planned hourly energy quantities and daily hourly prices. Real-time market settlement, on the other hand, is based on actual hourly energy deviations from the day-ahead plans, valued at real-time prices. [1], [4].

VI. Conclusions

With the current changes and new technologies in the generation, transmission, distribution, and consumption of electrical energy, it is extremely important to understand the functioning of the electricity market. Each market participant must translate this knowledge into planning their own operations to ensure the economic viability of their investments while ensuring the reliable and safe operation of the entire system.

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Electricity Market Risk Indicators

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***Abstract*—This paper introduces risk indicators that can be used in electricity trading. It presents their theoretical foundation, calculation methods, and their potential applications in electricity markets.**

Keywords—volatility, risk, profit, loss, Monte Carlo simulation

I. Introduction

Trading on the electricity market generates certain risks. Risk represents the threat of an undesired event occurring, deviating from the expected state or development. Consequently, there are multiple outcomes, with at least one of them being undesirable and leading to results different from the expected ones. Therefore, risk management is an essential component for energy entities engaged in electricity market trading because this market is complex and influenced by numerous variables [1]. Risks in this context can be categorized as financial and non-financial [2], [3].

A. Market Risk

This is the fundamental risk associated with trading electricity as a commodity in a liberalized market. The price of electricity in this market is influenced by various factors, including supply and demand, political changes, environmental factors, and others. Market risk may encompass:

- **Commodity risk** - changes in the price of electricity itself.
- **Currency risk** - the risk arising from fluctuations in exchange rates when trading electricity in international markets.
- **Interest rate risk** - if a subject has long-term financial commitments, interest rate risk involves possible changes in interest rates that will affect its costs or income.

B. Credit Risk

This risk arises from relationships with trading partners and involves the risk of counterparty defaulting on obligations. In the electricity market context, it could mean non-delivery or non-receipt of agreed-upon quantities of electricity, which has significant implications for the trading outcome.

C. Operational Risk

Operational risk includes various other risks not covered by market or credit risk. It may involve risks associated with technical malfunctions, sudden system outages, human errors, or other unexpected operational complications. This risk depends on the quality of internal processes and management.

Risk management in the electricity market is, therefore, a complex process that requires a wide range of tools and analytical approaches to address various aspects of risk and ensure the stable and secure operation of energy entities. In the following section, we will focus on defining and calculating specific risk indicators in such markets [4].

II. Profit & Loss Indicator

The Profit & Loss (P&L) indicator is used as a fundamental measure of performance in the liberalized energy market, representing the profitability of a position. A market position provides an aggregated view of the total volume of purchased/sold commodities in individual traded products on various markets. The Profit & Loss indicator is then defined as the realized profit or loss, representing the profitability of a closed position [2], [3].

As mentioned earlier, the P&L reflects the profit or loss from completed transactions. There are several approaches to calculating realized P&L, such as calculation based on the aggregated position or on individual transactions [5].

A. P&L Calculation Based on Aggregated Position

P&L represents the difference between the price of the position and the price of the realized transaction that closes the position, multiplied by the volume of the position that was closed. For example, after closing a long position, the following formula applies [5]:

$$P\&L = VCP * (TP - PP), \qquad (1)$$

where VCP represents Volume of Closed Position, TP is Transaction Price and PP is position price.

Depending on how the position is expressed (by hours, by products), the resulting P&L is the sum of partial hourly or product-based P&L.

In this approach, setting the price of the open position is crucial [5]:

- Price of the open position as **an average price**– the price of the open position is the average weighted price, with the volumes of individual transactions as weights.
- Price of the open position using the **FIFO (First in First Out)** – the closing transaction closes the oldest transaction.
- Price of the open position using the **LIFO (Last in First Out)** - the closing transaction closes the most recent transaction. The average price is calculated from the oldest trades that make up the open position.

III. Mark to Market indicator

The Mark to Market (MtM) is the second indicator used as a fundamental measure of performance in the liberalized energy market, representing the profitability of a position. Unlike the Profit & Loss indicator, the Mark to Market indicator is defined as an unrealized profit or loss, representing the market value of an open position [2], [3].

The goal of calculating the MtM indicator is to express the real value of an open position in individual markets. Market value represents the value of the position if it were realized in the market at the time of revaluation. By "realized," we mean either sold or bought [6].

Calculating MtM based on an aggregated position involves the difference between the acquisition price of the position and the market price of the open position, multiplied by the volume of the open position. For a long open position, the following formula applies [6]:

$$MtM=VOP * (MP - PP), \quad (2)$$

where VOP represents the Volume of Open Position and MP is Market Price.

Depending on how the position is expressed (by hours, by products), the resulting MtM is the sum of partial hourly or product-based MtM. In this approach, setting the price of the open position is crucial, and it can be determined similarly to P&L [6].

Calculating MtM based on transactions (revaluation) is computed as the difference between the transaction price and the market price in the given market, multiplied by the volume of the unrealized delivery. MtM is calculated only for unrealized - future deliveries [6].

For a buying transaction:

$$MtM= VFD * (MP - TP), \quad (3)$$

and for a selling transaction:

$$MtM=VRD * (TP - MP), \quad (4)$$

where VFD represents the Volume of Future Delivery and VRD is the Volume of Realized Delivery.

To express MtM for a trading book, the MtM of individual transactions belonging to the trading book is summed up.

IV. Value at Risk Indicator

Holding an open position carries a certain level of risk. This risk is caused by the unpredictability of commodity price movements in the commodity market, which can lead to losses due to the revaluation of the given position. To determine the extent of this risk, a metric is needed to measure it. One of the basic and probably most widely used indicators for measuring the risk arising from an open position is the Value at Risk (VaR) indicator. The Value at Risk represents the maximum loss of an open position caused by the price movements of individual products (risk factors) comprising the open position over a chosen time period and at a chosen probability level. In other words, for a selected time period of one day and a chosen probability of 95%, the calculated VaR value represents the potential loss generated by the open position, which the open position will not exceed with a probability of 95% within one day. From this definition, it follows that the basic parameters influencing the calculated value of VaR for a given open position are the time horizon (holding period of the open position) and the chosen probability [5], [6].

The Value at Risk of a given open position can be calculated using various methods. Different calculation methods can generally be referred to as Value at Risk methodologies. All methodologies share common input data required for calculation. The first category of input data is market data, usually price information. The second essential input consists of data describing the specific open position, specifically a set of risk factors that make up the open position. In the context of commodity trading, risk factors refer to a set of commonly traded products, and their allocation defines how the open position is distributed among these products to best match the position's diagram.

Three basic methods for calculating VaR are:

- Historical VaR calculation method,
- Parametric VaR calculation method,
- VaR calculation method using Monte Carlo simulation.

A. *Historical VaR calculation method*

The Historical VaR method, also known as historical simulation, is the simplest method in terms of calculation complexity. It belongs to the class of non-parametric methods. As implied by its name, the potential loss generated by the open position is simulated solely based on historical data, meaning data on the prices of individual risk factors that make up the open position. Using these data, changes in the value of the open position (P/L) are calculated, and subsequently, the value of the maximum loss that would occur with a given probability α over a specified past period is determined using a selected quantile [7].

B. *Parametric VaR calculation method*

The Parametric VaR calculation method is based on an assumption about the statistical distribution of the selected random variable. In general, when using parametric methods, it is necessary to decide in advance what we consider as the random variable (P/L, Rg, ra, or another risk factor). When making this decision, it is necessary to consider which parametric class best captures the risk factor. The parametric approach can be applied at two levels [7]:

- **Portfolio approach** – works with the distribution of P/L (Rg, ra, or another risk factor) for the entire portfolio.
- **Positional approach** – works with the distribution of P/L (Rg, ra, or another risk factor) for individual individual risk factors in the portfolio, which together create a multi-dimensional distribution of the random variable.

In addition to the distribution class, parametric methods need to consider whether it is conditional or unconditional distribution. The three most commonly used distribution classes to represent input parameters are [7]:

- Normal distribution,
- Student's t distribution,
- Lognormal distribution.

C. *VaR Calculation Method Using Monte Carlo Simulation*

The idea behind Monte Carlo methods is to repeatedly simulate a random process, such as price, yield, or another risk factor under analysis. To determine VaR, each simulation gives a possible value for the portfolio at the end of the period for which VaR is calculated. With a sufficient number of simulations, the simulated distribution of the portfolio's value will converge toward the actual, albeit unknown, distribution of the portfolio's value. From this distribution, it is then possible to estimate the empirical distribution of the portfolio's P/L and calculate VaR [7].

This simulation process requires a specific set of steps. Firstly, it is necessary to determine the stochastic process that describes the behavior of the risk factor. Subsequently, the parameters of this stochastic process need to be estimated, either based on historical risk factor development or empirically/expertly, for example, based on correlations with macroeconomic indicators. Then, a simulation is constructed for all risk factors, based on which the portfolio's value is calculated. The simulation of risk factors determines a hypothetical value of the portfolio. The simulation process is repeated a sufficient number of times to ensure that the hypothetical distribution of the portfolio's value is satisfactorily close to the actual, albeit unknown, distribution of the portfolio's value. Subsequently, VaR can be estimated from the hypothetical distribution [7].

In this way, Monte Carlo simulations can handle nonlinear dependencies of the portfolio's value on risk factors, heavy-tailed distributions, option-type dependencies, and the complexity of mutual and nonlinear dependencies between risk factors [7].

From the preceding text, it is clear that determining the stochastic process for individual risk factors is the most demanding and potentially error-prone aspect. In a broader sense, Monte Carlo methods, like parametric methods, work either in a portfolio or position approach [7]:

- *Portfolio approach*: The portfolio's value depends on only one risk factor, and modeling dependencies between random variables is not required.
- *Positional approach:* The portfolio's value depends on multiple risk factors, which may have complicated and nonlinear relationships.

V. UKAZOVATEĽ PROFIT AT RISK

While the VaR indicator is suitable for quantifying the risk of a liquid portfolio, commonly used in financial derivatives trading, where the assumption is the closing of positions through asset sales (or purchases), the Profit at Risk (PaR) indicator is appropriate for quantifying the risk for companies engaged in energy production from their own sources or selling energy to end clients [2], [8].

In contrast to VaR, which characterizes the potential change in portfolio (open position) value in the short term and is used for risk management in operational portfolio management, PaR characterizes the potential drop in expected profit in the long term. Mathematically, it represents the quantile distribution of profit [8].

The calculation of PaR is primarily carried out through Monte Carlo simulation, where various aspects affecting profit are simulated. In essence, we can divide these into two types of risks [5], [8]:

- Risks arising from changes in market prices,
- Risks arising from changes in portfolio volume.

The risk arising from price changes is determined by the volatility of forward and spot prices in the energy market. The risk associated with changes in portfolio volume is primarily relevant for companies planning energy production or supplying it to end customers. The specific case of selling to end customers is critical since it is not possible to predict portfolio consumption with complete certainty [8].

For companies engaged in energy production, it can also be essential to monitor variability in production costs related to the purchase of raw materials for energy production (such as gas, coal, CO_2, etc.).

Taking into consideration the aforementioned factors, the problems in calculating PaR can be divided into three main areas [8]:

- Selling to end customers and energy sourcing,
- Energy production and securing fuels,
- Realizing open positions in the market.

VI. Earnings at Risk Indicator

The Earnings at Risk (EaR) indicator, like the preceding indicators, represents market risk, and its role is to quantify the potential reduction in a company's earnings due to adverse events or market movements. It assesses the vulnerability of a company's profitability to various risk factors, allowing executives to understand and prepare for potential financial challenges [9].

The EaR indicator is typically expressed as a percentage or a monetary value, representing the estimated decline in earnings within a specified time frame and level of reliability.

The electricity market is exposed to a wide range of risks that can significantly impact a company's profits. These risks include electricity price fluctuations, changes in demand characteristics, developments in grid management, operational disruptions, and more. Therefore, the EaR indicator is particularly valuable in this market due to its ability to assess the financial implications of these risks. The EaR indicator can be applied in various situations in the electricity market, such as [8-10]:

- **Price Volatility**: Electricity prices can be highly volatile, driven by factors such as fuel prices, weather conditions, and supply and demand dynamics. EaR helps market participants, such as electricity producers and retailers, evaluate how price fluctuations may affect their earnings. For example, a company generating electricity can use EaR to estimate the potential impact on profits due to a sudden drop in wholesale electricity prices.
- **Demand Uncertainty**: Changes in electricity consumption patterns influenced by factors like economic conditions and seasonal fluctuations can lead to revenue fluctuations for companies trading in the electricity market. EaR assists energy companies and retail electricity providers in assessing the risk associated with deviations in electricity consumption.
- **Regulatory Risks**: The electricity market is subject to regulatory changes and policy developments that can affect market participants. EaR helps companies assess their financial exposure to regulatory risks, such as changes in renewable energy incentives or emission standards.
- **Operational Risks**: Operational disruptions, such as equipment failures or supply chain interruptions, can disrupt electricity production and distribution. EaR can quantify the potential impact of such disruptions on earnings and guide investments in risk mitigation strategies.

Calculating EaR involves several steps to quantify the potential earnings reduction resulting from identified risk factors. Like the preceding indicators, EaR calculation can be done parametrically, but it is most commonly performed using simulation, typically employing the Monte Carlo method.

VII. Credit at Risk Indicator

Unlike the previous indicators that focused on market risk, the Credit at Risk (CaR) indicator is used to assess and quantify potential losses that may arise from credit defaults or counterparty risks in the energy market [11].

Credit at Risk (CaR) is a financial risk management metric that quantifies the exposure a company or entity faces due to credit risk. It measures the potential financial loss that may occur if the counterparty fails to meet its contractual obligations, such as delivering or paying for energy products. CaR is typically expressed as a monetary value and represents the estimated loss within a specified time frame and level of reliability [11].

Credit risk is an integral part of transactions in the electricity market, making CaR a fundamental tool for market participants to assess and mitigate potential financial vulnerability. Its calculation involves several steps to quantify the potential financial loss associated with credit risk in energy market transactions. Different methodologies may vary depending on the organization's preferences and the availability of necessary data [11].

VIII. Conclusions

The article introduced fundamental risk indicators used in assessing volatility risk in electricity market trading. Their calculation is crucial for determining the strategy of electricity market participants when creating new positions or evaluating strategies used retrospectively.

Acknowledgment

This paper was supported under the project of Operational Programme Integrated Infrastructure: Support of research and development capacities in the field of generating advanced software tools designed to increase the resistance of economic entities against excessive volatility of the energy commodity market, ITMS2014+ code 313011BUK9. The project is co-funding by European Regional Development Fund.

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Application of Selected Risk Indicators in the Field of Electrical Power Systems

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***Abstract*— This paper introduces two risk indicators that can be used in electricity trading. It presents their theoretical foundation, ways of calculations, and their potential applications for electricity market participant's strategy improvement.**

Keywords—profit and loss, mark to market, day-ahead market

I. Introduction

Trading on the electricity market generates certain risks. Risk represents the threat of an undesired event occurring, differing from the expected state or development. There are, therefore, multiple development scenarios, with at least one of them being undesirable and leading to unachieved expected results. For this reason, risk management is an essential component for energy entities trading on the electricity market, as this market is relatively complex and influenced by many variables [1].

In this context, risks can be divided into three categories [2], [3]:

- Commodity risk,
- Credit risk,
- Operational risk.

Risk management in the electricity market is a complex process that requires a wide range of tools and analytical approaches to address various aspects of risk and ensure the stable and secure operation of energy entities. Various risk indicators are defined for this purpose in electricity markets, including Profit & Loss and Mark to Market indicators [4].

II. Profit&Loss Indicator

The Profit & Loss (P&L) indicator is used as a fundamental measure of performance in the liberalized energy market, representing the profitability of a position. A market position provides an aggregated view of the total volume of purchased/sold commodities in individual traded products on various markets. The Profit & Loss indicator is then defined as the realized profit or loss, representing the profitability of a closed position [2], [3].

III. Calculation of the Profit & Loss Indicator

There are several approaches to calculating realized P&L, such as calculation based on the aggregated position or on individual transactions [5].

A. Calculation of the Profit & Loss Indicator Based on Aggregated Position

P&L represents the difference between the price of the position and the price of the realized transaction that closes the position, multiplied by the volume of the position that was closed. For example, after closing a long position, the following formula applies [5]:

$$P\&L = VCP * (TP - PP), \qquad (1)$$

where VCP represents Volume of Closed Position, TP is Transaction Price and PP is position price.

Depending on how the position is expressed (by hours, by products), the resulting P&L is the sum of partial hourly or product-based P&L.

In this approach, setting the price of the open position is crucial [5]:

- Price of the open position as **an average price**– the price of the open position is the average weighted price, with the volumes of individual transactions as weights.
- Price of the open position using the **FIFO (First in First Out)** – the closing transaction closes the oldest transaction.
- Price of the open position using the **LIFO (Last in First Out)** - the closing transaction closes the most

recent transaction. The average price is calculated from the oldest trades that make up the open position.

B. Calculation of the Profit & Loss Indicator Based on Transactions

Realized P&L is calculated as the difference between the transaction price (TP) and the spot price (SP) in the given market, multiplied by the volume of the realized delivery (VRD). P&L is only calculated for realized deliveries. For a purchase transaction, the following equation applies [5]:

$$P\&L = VRD * (SP - TP), \quad (2)$$

and for a sale transaction:

$$P\&L = VRD * (TP - SP). \quad (3)$$

To express the P&L for a trading book, the P&L of individual transactions belonging to the trading book is summed up.

The disadvantage of this approach is that it is not possible to calculate realized P&L from a future delivery with a closed position. The advantage of this approach is that P&L can be used for accounting purposes, and there are no differences between accounting P&L and Trading P&L. Lastly, the advantage is the simplicity of aggregating P&L calculated in this way, such as by counterparties, by traders, by markets, and so on.

C. Calculation of the Profit & Loss indicator on Different Markets

The calculation of P&L based on aggregated positions is not affected by trading on different markets. However, when calculating P&L based on transactions, trading on different markets can have an impact. This occurs when calculating P&L from a realized delivery where the position is not netted. This is because the P&L calculation is done against the spot price, and spot prices can vary on different markets [5].

D. Calculation of the Profit & Loss indicator in Different Currencies

For contracts in different currencies, several approaches need to be considered regarding the exchange rate [5].

When calculating the P&L indicator based on aggregated positions, the position is composed of transactions in the same currency [5]. There is no need to address the currency conversion issue within the position itself, and P&L is calculated in the local currency of the transactions. P&L in another currency is then converted using:

- A single exchange rate as of the reporting date.
- The exchange rate on the day when the P&L was realized. The total P&L will be the sum of P&L on different days converted using the exchange rate applicable on the day when the P&L was realized.

If the position is composed of transactions in various currencies, the currency in which the position is expressed must be defined first. The transaction prices in other currencies are converted to the position currency using the current market exchange rate. Subsequently, the chosen method (average cost, FIFO, etc.) is applied.

When calculating the P&L indicator based on transactions, the P&L is calculated in the local currency of the contract for each hour. Possible currency conversion variants include [5]:

- Aggregating hourly P&L into a single value, which is then converted using the exchange rate as of the reporting date.
- Converting hourly P&L using the exchange rate applicable on the delivery day to which the P&L relates, followed by summing up the converted hourly P&L in another currency.

Currency exchange rates that can be used include [5]:

- Local central bank exchange rates - The advantage is alignment with accounting, as currency conversion in different countries is often linked to the local central bank.
- ECB (European Central Bank) exchange rates - The advantage is a unified methodology for exchange rate listings from a single institution, a single source of exchange rate listings, and consistent publication of exchange rate listings.
- Commercial bank exchange rates - The advantage is using the same rate for revaluation as used in settling the transaction, e.g., payment for delivered energy.
- Current market exchange rates - The advantage is revaluation at current market rates with the possibility of currency market speculation.

IV. Mark to Market Indicator

The Mark to Market (MtM) indicator is the second indicator used as a fundamental measure of performance in the open energy market, specifically in terms of position profitability. Unlike the Profit & Loss indicator, the Mark to Market indicator is defined as an unrealized profit or loss, representing the market value of an open position [2], [3].

V. Calculation of the Mark to Market Indicator

The aim of calculating the Mark to Market (MtM) indicator is to express the real value of an open position in various markets. Market value represents the position's value if it were to be realized on the market at the time of revaluation. The term "realized" here means sold or purchased [6].

Reasons for market revaluation of assets include:

- Determining the real value of the position – unrealized profit/loss.
- Determining the replacement cost of the position.
- Determining the actual exposure for credit risk assessment.
- Calculation of collateral requirements for the position.

- Accounting standards' requirements for revaluing speculative positions.

From the perspective of the MtM calculation methodology, it is crucial to establish:

- The price of the open position,
- The market price.

Similar to the Profit & Loss (P&L) indicator, there are multiple approaches to calculating the open position and the market price.

A. Calculation of the MtM Indicator Based on Aggregated Positions

MtM represents the difference between the acquisition price of the position and the market price of the open position, multiplied by the volume of the open position. For a long open position, the following equation applies [6]:

$$MtM = VOP * (MP - PP), \quad (4)$$

where VOP represents Volume of Open Position and MP is Market Price.

Depending on how the position is expressed (hourly, by products), the resulting MtM is the sum of partial hourly or product-based MtM.

In this approach, it is crucial to determine the price of the open position, which can be determined similarly to P&L as [6]:

- The price of the open position as **the average price**,
- The price of the open position using the **FIFO** method,
- The price of the open position using the **LIFO** method.

B. Calculation of the Mark to Market Indicator Based on Transactions

MtM revaluation is calculated as the difference between the transaction price and the market price in a given market, multiplied by the volume of the unrealized delivery. MtM is calculated only for unrealized - future deliveries [6].

For a purchase transaction, the following equation applies:

$$MtM = VFD * (MP - TP), \quad (5)$$

and for a sales transaction:

$$MtM = VFD * (TP - MP), \quad (6)$$

where VFD represents Volume of Future Delivery.

To express MtM for a trading book, the MtM of individual transactions belonging to the trading book is summed up.

The disadvantage of this approach is that MtM includes the value of profit and loss from a future delivery when the position is closed. This is no longer sensitive to market developments. Methodically correctly, this should be realized P&L. The advantage of this approach is that MtM can be used for accounting purposes, and there are no differences between accounting MtM and Trading MtM. Lastly, the advantage is the simplicity of aggregating MtM calculated in this way, such as by counterparties, by traders, by markets, and so on.

C. Calculation of Market Price for the MtM Indicator

Depending on the granularity of the open position, it is necessary to calculate the market price for each unit of the open position [6]:

- **Open position by products** – The market price is directly obtained from the market. This represents a clear determination of the price based on the market price valid at the time of revaluation. The only potential issue might be insufficient market liquidity, meaning that the position cannot be revalued at this price, e.g., due to position size - the position is either too small or too large.
- **Open position by hours** - The market price of future deliveries by hours is not published on the market. It needs to be calculated. This calculation is referred to as the benchmark curve calculation for revaluation.

D. Determination of the hourly benchmark curve for individual markets

The hourly benchmark curve is sometimes referred to as the HPFC curve (hourly price forward curve). The HPFC curve is used for the revaluation of profiles that have a non-standard behavior and are not directly tradable on the market. The goal of the curve is to determine the price of electricity for each future hour.

General principles for creating the HPFC curve include:

- **Establishing a seasonal curve** – distributing prices throughout the year. The curve is adjusted based on historical spot prices, assuming that typical seasonal patterns repeat each year. The seasonality curve will contain annual, weekly, and daily components. Seasonal patterns occur due to weather conditions or economic and trading activities.
- **Adaptation of the seasonal curve** – adjusting the seasonal curve based on futures prices to eliminate arbitrage opportunities.
- **Curve adaptation** – adjusting the curve based on PEAK and OFFPEAK prices to eliminate arbitrage opportunities.
- **Adjustment of hourly prices** – incorporating an hourly profile of daily prices.
- **Curve smoothing** – partially suppresses the seasonality of the curve.

E. Calculation of the MtM Indicator on Different Markets

When calculating MtM across different markets, various markets and current market prices influence it. If the market is sufficiently liquid, it is most suitable to use prices directly from the market where the position is. If the market is not sufficiently liquid, it is necessary to use prices from another relevant market to which this market is linked.

For revaluation, the following types of prices can be used:

- **Close of bussiness prices** – suitable for revaluation for accounting purposes, regular revaluation.
- **Current market prices** – Suitable for revaluation during significant market fluctuations, e.g., for assessing credit exposure.

VI. Exmaple of P&L a MtM indicators applications

The application of P&L and MtM indicators for a 10 MW powerplant on a day-ahead market is shown in Table 1.

TABLE I. VALUES OF P&L AND MTM INDICATORS

	P&L				**MtM**		
	VRD	***TP***	***SP***	***P&L***	***VOP***	***MtM***	***MtM$_{cor}$***
H	**(MWh)**	**(€/MWh)**	**(€/MWh)**	**(€)**	**(MWh)**	**(€)**	**(€)**
1	2	17.00	104.29	174,58	8	-698.32	-371.45
2	2	17.00	68.00	102,00	8	-408.00	-190.00
3	2	17.00	55.39	76,78	8	-307.12	-126.95
4	2	17.00	61.33	88,66	8	-354.64	-156.65
5	2	17.00	72.33	110,66	8	-442.64	-145.32
6	2	17.00	129.85	225,70	8	-902.80	-263.55
7	5	42.00	119.52	387,60	5	-387.60	-143.04
8	10	84.00	134.76	507,60	0	0.00	0.00
9	10	84.00	105.36	213,60	0	0.00	0.00
10	10	84.00	85.99	19,90	0	0.00	0.00
11	10	84.00	66.94	-170,60	0	0.00	0.00
12	10	84.00	65.56	-184,40	0	0.00	0.00
13	10	84.00	73.74	-102,60	0	0.00	0.00
14	10	84.00	73.24	-107,60	0	0.00	0.00
15	10	84.00	77.37	-66,30	0	0.00	0.00
16	10	84.00	77.63	-63,70	0	0.00	0.00
17	10	84.00	91.82	78,20	0	0.00	0.00
18	10	84.00	125.89	418,90	0	0.00	0.00
19	10	84.00	164.49	804,90	0	0.00	0.00
20	5	42.00	195.00	765,00	5	-765.00	-294.00
21	5	42.00	168.55	632,75	5	-632.75	-379.65
22	2	17.00	124.85	215,70	8	-862.80	-355.40
23	2	17.00	98.34	162,68	8	-650.72	-341.70
24	2	17.00	87.55	141.10	8	-564.40	-287.75
Sum				**4 431.11**		**-6 976.79**	**-3 055.46**

The columns VRD represent the amount of energy for a transaction on a day-ahead market, TP the transaction price and SP the spot price. The values of P&L indicators for each hour is calculated in the column labeled P&L and shows the profit/loss of hourly transactions. The total profit of the day is 4 431.11 €, but it could be seen that there are hours with the loss as well (form 11 a.m. to 16 a.m.).

Therefore, the indicator MtM was calculated to indicate the loss of opened positions (VOP), which represents the energy that wasn't successfully traded on the day-ahead market. The total value of MtM indicator is -6 976,79 €. It is higher than the profit calculated by P&L indicator and so it indicates that some contra measures need to be done to decrease the loss of open positions and increase the total profit.

Such a measure could be the change of the fuel supplier leading to the cut of the generation costs and bigger number of hours with higher VRD. If the production cost would be decreased by 30 %, the expected value of MtM indicator (column MtM$_{cor}$) would be -3 55,46 € what is only 44 % of the original loss.

VII. Conclusions

The article introduced two fundamental risk indicators, Profit and Loss and Mark to Market, which are used in assessing volatility risk in electricity market trading. For each indicator the various ways for calculation were described as well. As could be seen from the given example at the end of the paper, the use of P&L and MtM indicators can lead to better strategy on the market and so to the bigger profit.

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Rapid prototyping in the Research centre of University of Žilina

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***Abstract*— Rapid prototyping in the university environment encompasses a range of activities that involve the use of advanced technologies. It serves as a catalyst for innovation, research, and education across various disciplines, providing students and researchers with practical tools and experiences that can have a broad impact on society and industry. An integral part of the scientific research activities at the UNIZA Research Centre is the development of components and functional prototypes of the developed equipment. Developing wearable electronics prototypes involves a multidisciplinary approach that combines aspects of electronics design, hardware development, software development, and ergonomic design. In this paper we focus on the mechanical part prototyping.**

Keywords—simulation; rapid-prototyping; 3D modeling; 3D printing; Fusion360.

I. INTRODUCTION

Rapid prototyping [1] in the university environment encompasses a range of activities that involve the use of advanced technologies, such as 3D printing, to create physical prototypes of objects, components, or systems quickly and iteratively. This approach is highly beneficial for academic institutions and research settings, as it supports various disciplines and research projects. Rapid prototyping is typically utilized in following areas:

1. Research and Development: Universities often conduct research in fields such as engineering, design, materials science, and biotechnology. Rapid prototyping enables researchers to create prototypes of their ideas or innovations swiftly. This is particularly valuable when testing and refining new concepts or technologies.
2. Engineering and Design Courses: Many universities offer courses in engineering, industrial design, architecture, and related fields. Rapid prototyping facilities are essential for students to gain hands-on experience in designing and building prototypes. It helps bridge the gap between theoretical knowledge and practical skills.
3. Innovation Hubs and Makerspaces: Universities often establish innovation hubs or makerspaces equipped with 3D printers, laser cutters, CNC machines, and other prototyping tools. These spaces provide students, faculty, and sometimes even the local community with access to rapid prototyping equipment and expertise.
4. Interdisciplinary Collaboration: Universities are hubs of interdisciplinary collaboration. Rapid prototyping facilities can serve as common ground where researchers and students from various departments work together on projects that require physical prototypes. This fosters creativity and innovation.
5. Product Development: Universities often engage in product development projects, either in collaboration with industry partners or as part of technology transfer initiatives. Rapid prototyping facilitates the creation of prototypes for new products, which can be critical for securing funding and attracting investors.
6. Biomedical and Healthcare Research: In the medical and healthcare fields, rapid prototyping is used for creating custom medical devices, prosthetics, anatomical models, and tissue engineering. Universities with strong biomedical programs often have dedicated labs for these purposes.
7. Art and Sculpture: Even in the arts, rapid prototyping has found a place. Artists and

sculptors use 3D printing and other rapid prototyping techniques to bring their creative visions to life in novel ways.

8. Environmental Sustainability: Some universities focus on sustainability and use rapid prototyping for research and projects related to sustainable design, recycling, and waste reduction.
9. Entrepreneurship and Startups: Universities often support entrepreneurial activities, and rapid prototyping plays a significant role in helping students and faculty prototype and test their startup ideas before seeking funding or launching a business.

Overall, rapid prototyping at our university serves as a catalyst for innovation, research, and education across various disciplines, providing students and researchers with practical tools and experiences that can have a broad impact on society and industry.

An integral part of the scientific research activities at the UNIZA Research Centre is the development of components and functional prototypes of the developed equipment. In the phase of the development process, 3D modeling tools are used, which allow, in addition to the modeling itself, the simulation of several mechanical parameters of the designed designs due to the influence of physical processes and the subsequent 3D printing of model designs using SLS (selective laser sintering) technology [2], postprocessing of the surface of the components and finalization of the prototypes.

II. Materials and methods

Three-dimensional (3D) modeling is a critical technique used in various fields, including computer graphics, engineering, architecture, animation, and scientific visualization. There are several approaches to 3D modeling, each suited to different applications and requirements. The most common 3D modeling approaches are:

1. Polygonal Modeling:
   a. Description: Polygonal modeling is one of the most widely used 3D modeling techniques. It represents 3D objects using a mesh of interconnected polygons (typically triangles or quadrilaterals). Each polygon is defined by its vertices, edges, and faces.
   b. Applications: Video games, computer graphics, animations, and real-time simulations often use polygonal modeling due to its efficiency in rendering and manipulation.
2. NURBS Modeling (Non-Uniform Rational B-Spline):
   a. Description: NURBS modeling represents objects as mathematical curves and surfaces defined by control points. It offers precise control over the shape and smoothness of surfaces.
   b. Applications: NURBS modeling is widely used in CAD (Computer-Aided Design), industrial design, automotive design, and aerospace engineering due to its ability to create complex and accurate shapes.
3. Parametric Modeling:
   a. Description: Parametric modeling uses mathematical equations to define objects. Parameters and constraints are used to modify and control the shape, size, and behavior of the 3D model.
   b. Applications: Parametric modeling is commonly employed in engineering and product design, where the relationships between different parts of an object need to be maintained. Software like SolidWorks and Autodesk Inventor use parametric modeling.
4. Sculpting:
   a. Description: Sculpting involves the digital manipulation of a 3D mesh by pushing and pulling vertices to create organic and free-form shapes. Sculpting tools simulate the physical sculpting process.
   b. Applications: Sculpting is often used in character modeling for animation and visual effects, as well as for creating detailed organic models.
5. Volumetric Modeling:
   a. Description: Volumetric modeling represents objects as a grid of voxels (3D pixels) within a 3D space. Each voxel has a specific value, such as density or color.
   b. Applications: Medical imaging, scientific visualization, and certain simulation applications rely on volumetric modeling to represent data in 3D space.
6. Procedural Modeling:
   a. Description: Procedural modeling involves defining objects using algorithms and rules rather than manual manipulation. It's often used for generating complex and repetitive structures.
   b. Applications: Procedural modeling is employed in computer graphics for generating terrain, cityscapes, foliage, and other natural or synthetic environments.
7. Photogrammetry:
   a. Description: Photogrammetry creates 3D models by capturing and analyzing photographs of real-world objects or scenes. Software processes these images to generate a 3D model.
   b. Applications: Archaeology, geology, architecture, and 3D scanning of objects use

photogrammetry to create accurate 3D representations.

8. CAD Modeling (Computer-Aided Design):
   a. Description: CAD modeling focuses on creating precise 3D models of products or engineering components with detailed measurements and specifications.
   b. Applications: CAD modeling is fundamental in engineering, architecture, product design, and manufacturing for creating functional and manufacturable designs.
   c.

The choice of 3D modeling approach depends on the specific application, the required level of detail and accuracy, and the available software and tools. Many 3D modeling software packages support multiple approaches, allowing users to select the most suitable method for their project [3].

Prototype modeling, parameter simulations and creation of network models for 3D printing at the Research centre are implemented in the educational version of the cloud software environment Fusion 360 [4]. In addition to basic and advanced 3D modeling features, the environment also includes online tools for simulating physical parameters and the behavior of designed models under various external influences, such as static loads, mechanical stresses due to external forces, thermal resistance, and similar.

Another advantage of the Fusion 360 environment is the ability to link the design of electronic parts (PCBs) created in the Eagle environment with the design of 3D models, allowing online optimization and customization of individual component parameters or the resulting models. The output of the Fusion 360 development environment is the final 3D network model in STL format, which serves as input for the 3D printer operator software and the optimization of individual print parameters.

III. Wearable electronics prototype development

Developing wearable electronics prototypes involves a multidisciplinary approach that combines aspects of electronics design, hardware development, software development, and ergonomic design. We focus on the mechanical part prototyping.

By a specific application of the above-mentioned techniques, a working prototype of wearable electronics in the form of a bracelet was developed. The prototype contains several electronic modules - a module with a sensor, a module for processing the signal from the sensor, a module for displaying the processed data, a battery, and switches. It was necessary to design a functional case for the above components with the most compact dimensions.

In a first step, the individual electronic components placed on the PCB were modeled in a graphical environment at a scale of 1:1, Fig.1.

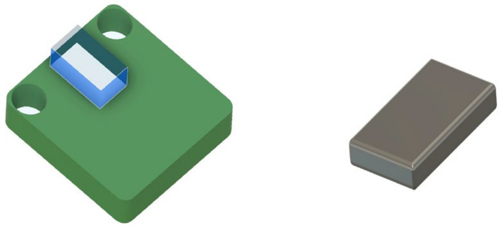

Fig. 1 Modeled electronic components.

Subsequently, considering the function of the individual components and their dimensions, their positioning in space was designed and subsequently the rotation and positioning of the modules was optimized so that the minimum dimensions of the housing were respected, Fig.2.

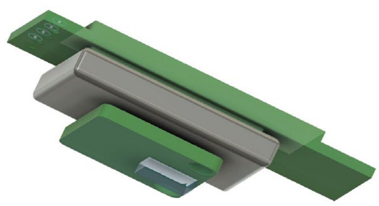

Fig. 2 Positioned components.

In the second step, measurements were taken on the arranged set of components to design the final dimensions of the housing and to determine the mounting holes for the placement of the electronic components. At the same time, the requirements for the properties of the case - the method of attachment of the strap, the concealment, the possibility of serviceability, as well as the requirements for resistance to mechanical stress at the points of attachment of the bracelet and the heat transfer through the material that was available in 3D printing were determined.

In the third step, a 3D model of a two-piece case in Fig. 3 with a split bracelet attachment option was modeled based on the above parameters and requirements.

Fig. 3 Case design.

IV. RESULTS

The resulting model design was subjected to simulation in the Fusion 360 graphical environment for mechanical stress at the bracelet attachment points and simulation for heat transfer through the chosen material - PA12 in Fig.4.

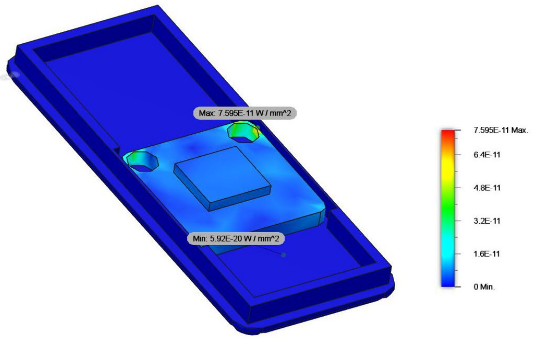

Fig. 4 Mechanical stress simulation.

The PA 12 material parameters are presented in Tab. 1.

TAB. 1 PA12 MATERIAL PARAMETERS.

PA 12 - Nylon - PA 603-CF (with EOS P 3D Printers)

Density	1.1E-06 kg / mm^3
Young's Modulus	2881 MPa
Poisson's Ratio	0.18
Yield Strength	25.86 MPa
Ultimate Tensile Strength	32.74 MPa
Thermal Conductivity	5.5E-04 W / (mm C)
Thermal Expansion Coefficient	4.347E-05 / C
Specific Heat	1530 J / (kg C)

Fig. 5 shows the final version of the wearable electronics prototype completely designed and built at the UNIZA Research Centre.

Fig. 5 Prototype of the wearable electronics.

V. CONCLUSIONS

Rapid prototyping is an essential part of any pursuit of scientific and technological progress. It brings the possibility of quick verification of assumptions in actual deployment and thus has a positive impact on the project budget. At the Research centre of UNIZA, we use 3D modelling of mechanical components of wearable electronics using Fusion360 modelling software, with the designed models going through several types of simulations before production, depending on the intended use. After their verification, we print them on a 3D printer and complete them with the appropriate electronics. This process significantly saves time and money and is well suited for our research and development.

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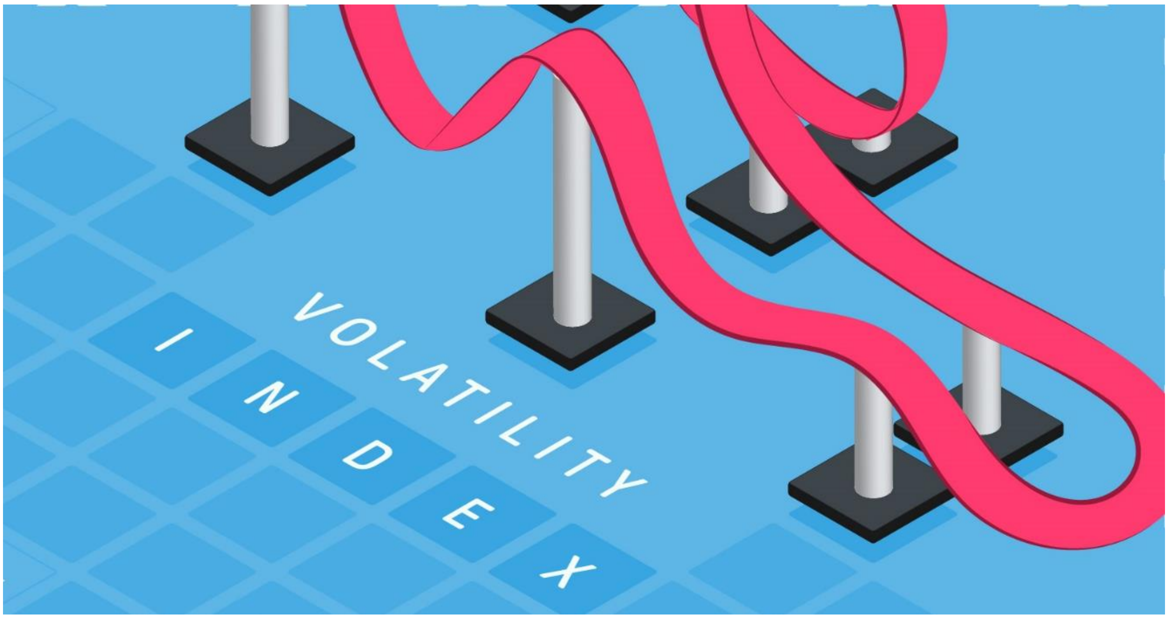

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