TEEP 2024 Internship Program Renewable Energy & Power System Lab

The TEEP 2024 internship program brought together a diverse group of students, all working under the guidance of **Professor Yuan-Kang Wu** at the **Renewable Energy and Power System Laboratory** at **National Chung Cheng University**.

Supervisor: Prof. Yuan-Kang Wu

Contact email: allenwu@ccu.edu.tw

Contact Phone: 05-2720411 EXT: 33232

Address: No.168, University Road, 62102, Mingshung, Chiayi, Taiwan

Table 1: Summary of Student Research Projects

Student Name	Research Topic	University	Research Period	Country
Wendy Tang	Comparison between metaheuristic algorithms: Particle Swarm Optimization (PSO), Grey Wolf Optimization (GWO), Artificial Bee Colony (ABC), and Whale Optimization Algorithm (WOA)	Universiti Malaysia Perlis	April 1, 2024 – June 22, 2024	Malaysia
Ly Thoi Hung	Frequency control for Power System with Wind Turbines	University of Technology, Vietnam National University, HCMC	July 1, 2024 – September 9, 2024	Vietnam
Ling Jie Qi	Review on extreme weather event related power system resilience	Monash University Malaysia	July 1, 2024 – September 9, 2024	Malaysia
Tran Gia Huy	Research on the influence of spatial and temporal aspects in forecasting	University of Technology, Vietnam National University, HCMC	June 3, 2024 – August 24, 2024	Vietnam

Huynh Minh Trieu	Resilience of The Power System in Extreme Weather	University of Technology, Vietnam National University, HCMC	June 3, 2024 – August 24, 2024	Vietnam
Bui Khanh Hao	Campus Microgrid Projects and Experience	University of Technology, Vietnam National University, HCMC	June 3, 2024 – August 24, 2024	Vietnam
Lam Hong Phuc	The method and control technologies to reduce the impact of low inertia on power system with a high penetration of renewable power generation	University of Technology, Vietnam National University, HCMC	June 15, 2024 – August 27, 2024	Vietnam
Nguyen Thuy Phuong	Research to improve the controller and simulate the averaged three-phase voltage source converter system	University of Technology, Vietnam National University, HCMC	February 26, 2024 – August 10, 2024	Vietnam

The internship provided students with the opportunity to engage in cutting-edge research on renewable energy systems, power grid stability, and energy storage solutions.

Throughout the program, students applied their knowledge in electrical engineering and developed innovative solutions to real-world challenges. Projects ranged from optimizing wind farm voltage control to diagnosing faults in photovoltaic systems, all contributing to the growing field of sustainable energy. Under the supervision of Prof. Yuan-Kang Wu, students gained practical experience, enhanced their research skills, and contributed valuable insights into renewable energy and power systems.

This report summarizes the individual research projects completed during the TEEP 2024 internship program, highlighting the key findings and contributions of each student.

Wendy Tang

Topic: Comparison between metaheuristic algorithms: Particle Swarm Optimization (PSO), Grey Wolf Optimization (GWO), Artificial Bee Colony (ABC), and Whale Optimization Algorithm (WOA)

Research Period: April 1, 2024 – June 22, 2024

Abstract: Population-based metaheuristics algorithms are optimization techniques inspired by natural processes, such as evolution or swarm behavior. These algorithms operate on a population of potential solutions, iteratively improving them through mechanisms like particle movement, leadership hierarchies, social interaction, hunting strategies, and foraging behaviors. Examples include Particle Swarm Optimization (PSO), Grey Wolf Optimizer (GWO), Artificial Bee Colony (ABC), and Whale Optimization Algorithm (WOA). The goal is to explore the solution space effectively to find near-optimal solutions to complex problems. In this report, various metaheuristic algorithms

will be explored and compared in terms of their working principles, strengths, weaknesses, and applications of Economic Load Dispatch (ELD). Understanding the underlying mechanisms of these algorithms provides insights into their potential applications in various fields and their effectiveness in solving complex optimization problems.

Key Findings:

The main aim of the economic dispatch problem is to minimize the total cost of generating real power (production cost) at various stations while satisfying the loads and the losses in the transmission links. To start with the economic factor in power system operation, the allocation of real power at generator buses is focused. The ELD problem under consideration here has 3 generation units, each unit has a range of fuel cost that it can use as listed in Table 1. The objective here is to assign each unit with the proper amount of allowed fuel cost that results in a total minimum of fuel cost for all units. The optimization has to satisfy a set of constraints and the power demand of 1000 MW such that the optimum solutions will always be feasible. The objective function that is used to evaluate ELD solution P in terms of fuel costs is formulated in Eq. (1)

$$\min F(P) = \sum_{i=1}^{N} F_i(P_i) \tag{1}$$

where F(P) is the total fuel cost for N units and F_i is a function used to calculate the fuel cost for unit P_i. The calculation of fuel cost F_i (P_i) for unit P_i is given in Eq. (2).

$$F_i(P_i) = \left[a_i P_i^2 + b_i P_i + c_i + \left|e_i \sin\left(f_i\left(P_i^{min} - P_i\right)\right)\right|\right] \tag{2}$$

The smooth coefficients (a_i, b_i, c_i) and the non-smooth coefficients (e_i, f_i) related to the generation unit i. The sinusoidal function shows the effect of the valve-point load obtained waves in the trend of the heat-rate. That revealed more challenges to avoid being stuck in local optimum solutions.

Table 1. Coefficients and Boundaries of 3 Generation Units

i	Quadratic Cost Coefficient (Rs/MWh^2): a	Linear Cost Coefficient (Rs/MWh): b	Generator Capacity (MW): c	e	f	Lower boundary: P^{min}	Upper boundary: P^{max}
1	0.00156	7.92	561	300	0.0315	150	600
2	0.00194	7.85	310	200	0.042	100	400
3	0.00482	7.97	78	150	0.063	50	200

Assume that 50 search agents were considered (n = 50) and the maximum number of iterations was set to 1000. The worst and best results under 30 independent runs are shown in Table 2. Statistically, ABC performs the best on this optimization function, the number of minimum costs that ABC searched for is the most compared to other algorithms. For the 30 independent runs, ABC can find global minima with a highly probabilistic and consistency with a standard deviation of 0.74. GWO has a higher standard deviation value which is 40.37, followed by the WOA of 86.81. Although the best cost that WOA obtained is lower than GWO, the outputs of WOA are less consistent than GWO. PSO performs the worst with the highest cost obtained and standard deviation, which means it is poor in exploration, exploitation and consistency.

Table 2. ELD Solutions of PSO, GWO, ABC and WOA

Algorithm	PSO				GWO				ABC				WOA			
Result	P1	P2	P3	Cost	P1	P2	P3	Cost	P1	P2	P3	Cost	P1	P2	P3	Cost
Min	555.91	255.07	188.98	9849.41	450.68	400.00	149.42	9607.76	450.23	400.00	149.77	9600.07	450.07	399.35	150.57	9600.74
Max	599.97	358.85	114.00	10915.24	555.14	400.00	52.50	9797.15	449.11	400.00	150.96	9603.17	558.78	291.80	149.42	9906.36
Mean	10199.56				9677.09				9600.66				9710.97			
Std. Dev.	234.78				40.37				0.74				86.81			

The convergence characteristics of 30 runs for PSO, GWO, ABC and WOA are shown in Fig. 1. It can be observed that PSO performs the fastest in terms of convergence. However, precocious convergence results in a lower-quality and inconsistent result. ABC, on the other hand, converges slightly slower than the PSO but still obtains the best and most consistent results. The convergence speeds of GWO and WOA seem equal but the convergence curves of GWO show more better consistency.

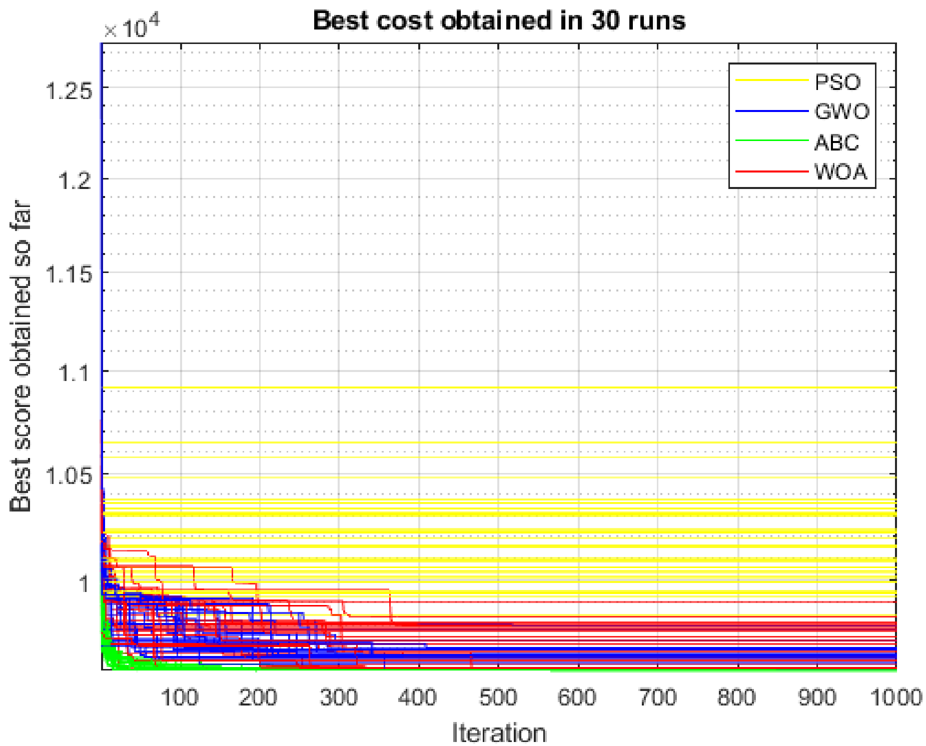


Figure 1. Convergence Characteristics of 30 Runs for PSO, GWO, ABC and WOA

Ly Thoi Hung

Topic: Frequency control for Power System with Wind Turbines

Research Period: July 1, 2024 – September 9, 2024

Abstract: As the demand for power supply and the environmental concerns surrounding the power industry grew, the integration of large-scale renewable energy generation units was inevitable. Wind power, specifically wind turbines, is a notable choice for renewable energy due to several advantages such as being abundant, cost-effective, and versatile in its application. As advantageous as it might be, if wind turbines are to be widely integrated into the power system, they will need to be able to participate in load frequency regulation or they will pose a great risk to the stability of the power system. This research will briefly survey available methods for controlling the wind turbine in frequency control.

Key Findings: The report presents the basics of frequency control, including the frequency model of the synchronous generator and load, the model of the hydraulic and thermal turbines, and the control methods for the synchronous generator. Additionally, the equivalent method for a multi-generator system is also presented. A simplified DFIG wind turbine model is presented. Based on the given model, simulations with both synchronous generators and wind turbines are conducted at fixed wind speeds and variable windspeed scenarios to evaluate the given model. The simulation also compares the frequency response between the system with and without wind turbines.

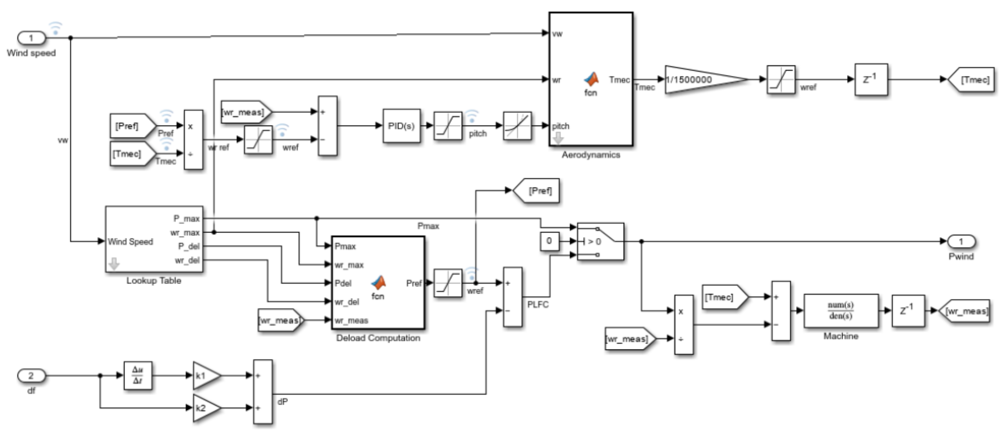


Figure 2. The simplified wind turbine in Simulink

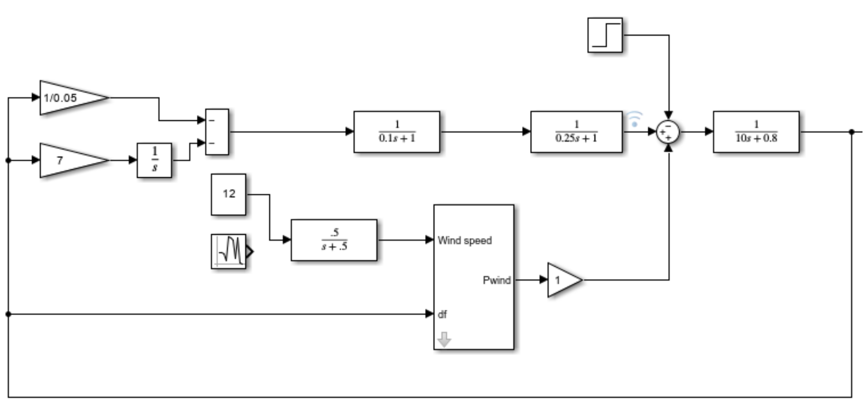


Figure 3. The simulation model in Simulink

Fig. 2 present the simplified model and Fig. 3 present the evaluating model adopted to Simulink. First, the turbine is in MPPT mode, and the wind speed is fixed at 12m/s when the load change occurs. Assume that the system is in a steady state before the load changes. The load change is set to be 0.2 p.u. The system base frequency is 60Hz. The result in Fig. 4 is for comparison between frequency response without the wind turbine and when the wind turbine is MPPT mode.

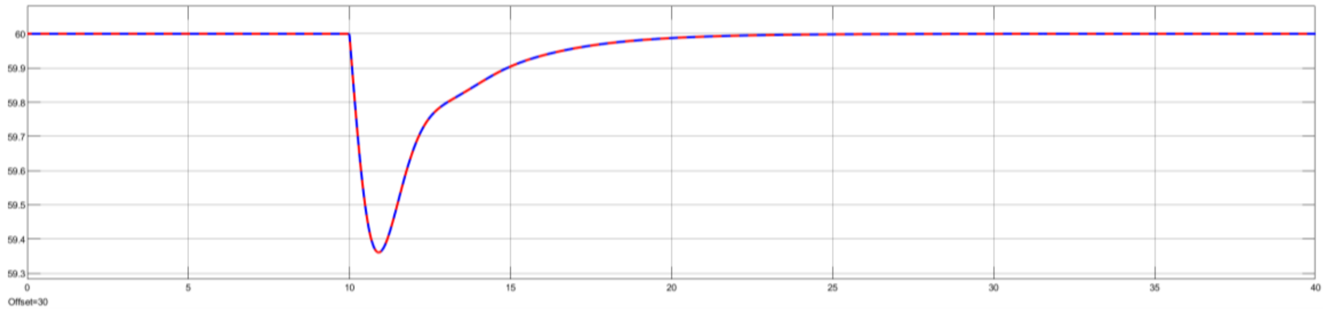


Figure 4. Comparing between no wind turbine support and wind turbine in MPPT mode

Next, the turbine is in Deloaded mode and will participate in frequency regulation. The wind speed is fixed at 12m/s when the load change occurs. Assume that the system is in a steady state before the load changes. The load change is set to be 0.2 p.u. The system base frequency is 60Hz. The result in Fig. 5 is for comparison between frequency response when the wind turbine is MPPT and when the wind turbine is 10% deloaded.

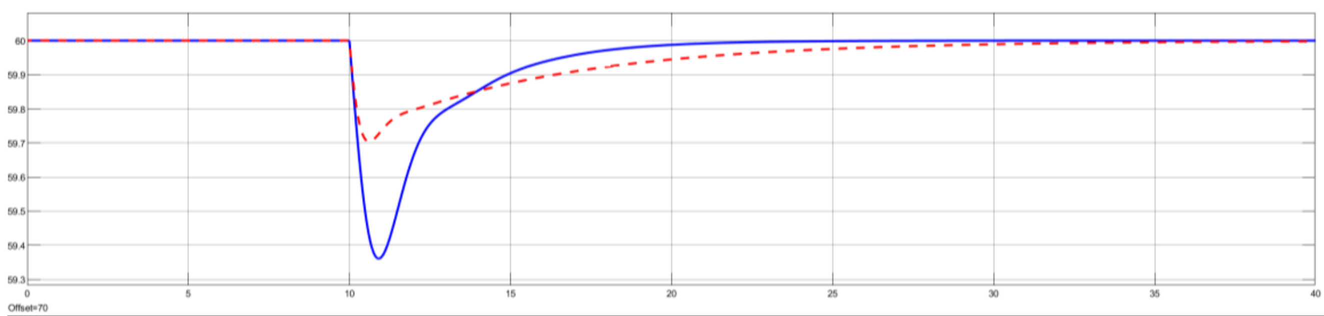


Figure 5. Comparing between MPPT mode and 10% deloaded mode

Finally, the model is simulated in variable wind speed condition, ranging from 6 m/s to 14 m/s as shown in Fig. 6. Also, The simulation ran for 100s. At 20s, a load of 0.2 p.u is added and at 70s, a load of 0.3 p.u is removed, as illustrated in Fig. 7.

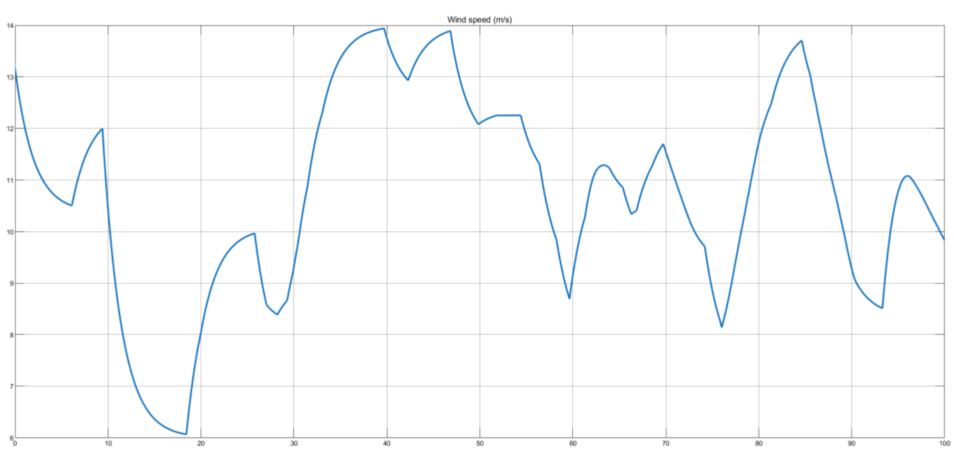


Figure 6. Variable wind speed

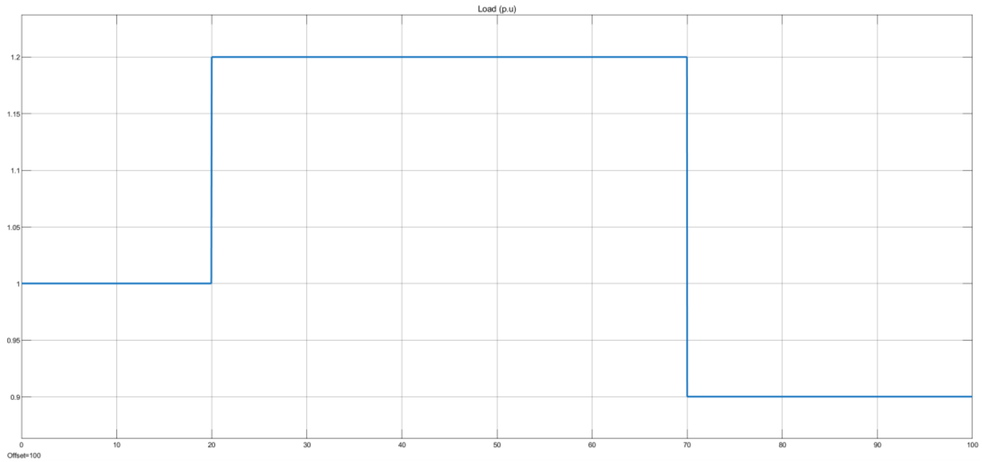


Figure 7. Load change

Fig. 8 present the result Pitch Angle and Frequency. Fig. 9 present the rotor speed.

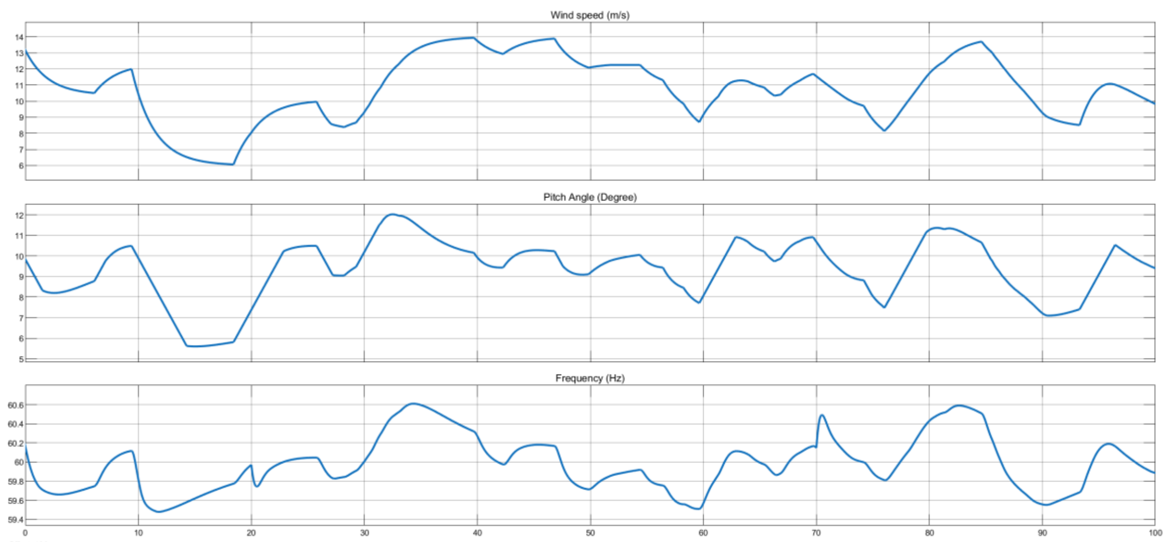


Figure 8. Wind speed (m/s), Pitch angle (degree) and Frequency (Hz)

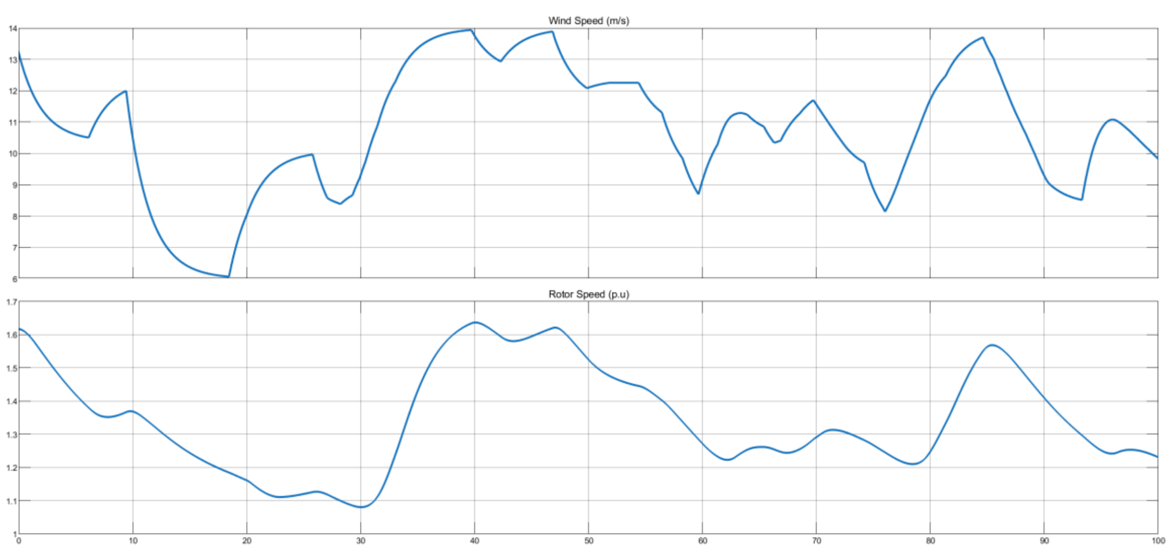


Figure 9. Wind Speed (m/s) and Rotor Speed (p.u)

Ling Jie Qi

Topic: Review on extreme weather event related power system resilience

Research Period: July 1, 2024 – September 9, 2024

Abstract: Power systems are the backbone of modern society, providing a continuous supply of electricity essential for maintaining daily life and economic activity. Despite their critical role, these systems remain vulnerable to high-impact, low-probability events such as typhoons, hurricanes, wildfires, earthquakes, and floods. These extreme weather events can result in prolonged outages, severe damage to key components like transmission lines, substations, and power plants, and significantly disrupt power supply. The increasing frequency and intensity of such events emphasize the urgent need to improve the resilience of power systems. This involves identifying and characterizing weather-related hazards, assessing vulnerabilities in system components, analyzing the system's behavior under stress, evaluating its current resilience levels, and determining the effectiveness of strategies aimed at strengthening resilience. While considerable research has been conducted on resilience definitions, metrics, evaluation methods, and enhancement strategies, there is still no universal standard or consensus in the field. This research conducted a comprehensive review of power system resilience during extreme weather events, focusing on five key areas: (1) definition, (2) metrics, (3) modeling, (4) evaluation, and (5) enhancement. Additionally, the research addresses current challenges and future directions for improving resilience.

Key Findings: This report highlights the critical need to enhance the resilience of power systems, which are essential for modern life but vulnerable to severe weather events such as typhoons, hurricanes, wildfires, earthquakes, and floods. The review examines key aspects of power system resilience, including definitions, metrics, modeling approaches, evaluation methods, and improvement strategies. It identifies significant gaps in current research, such as the reliance on traditional reliability metrics that do not adequately address High-Impact Low-Probability (HILP) events or capture dynamic, spatiotemporal impacts. The report calls for the development of a universal standard for resilience metrics and emphasizes the importance of integrating advanced modeling techniques, such as big data analysis and deep learning, to improve accuracy. Additionally, it stresses the need for comprehensive assessments of system vulnerabilities and behaviors under extreme conditions to enhance resilience and better manage the challenges posed by severe weather events.

The resilience trapezoid is an improved version of the resilience curve, fully capturing the multiphase characteristics of resilience. It divides resilience into several phases: resilience state, event progress state, post-event degraded state, restorative state, and post-restoration state. These phases represent the key capabilities of a resilient power system while also accounting for both operational and infrastructure resilience.

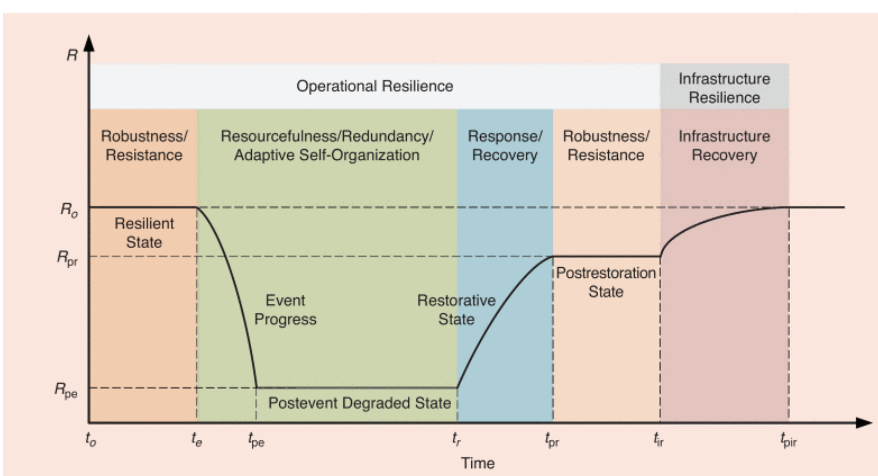


Figure 10. Resilience trapezoid

Several metrics had been proposed to assess the resilience based on the system's features or attributes.

Table 3. Commonly used resilience metrics and associated formula

Metric	Description	Formula
SAIFI, SAIDI, CAIDI	1. SAIFI: Average number of outages per customer per year. 2. SAIDI: Total number of minutes/hours of interruption per customer per year. 3. CAIDI: Average time required to restore service.	$SAIFI = \frac{CI}{CS}, SAIDI = \frac{CMI}{CS},$ $CAIDI = \frac{SAIDI}{SAIFI}$ where: CI = Customers interrupted CMI = Customer minutes interrupted CS = Customers served
Ratio of Area Under Target vs. Actual Performance	Resilience defined as the ratio of the area under the target performance curve to the actual performance curve.	-
Maximum Reduction in System Performance and Loss	Resilience metric based on maximum reduction in system performance and loss incurred.	$R = 100(1 - \frac{L_{Mm}}{L_{max}})$ where: L_{Mm}= Measure of maximum reduction in system performance L_{max}= Loss incurred when all loads and DG are disconnected
Event Duration and Profile	Resilience metric based on event duration and profiles of failure and recovery.	$Resilience\ (Re) = \frac{T_i+F\Delta T_f+R\Delta T_r}{T_i+\Delta T_f+\Delta T_r}$ where: F = Failure profile R = recovery profile T_i= Time to incident ΔT_f= Failure duration ΔT_r= Recovery duration
Cobb-Douglas Production Function	Resilience based on the Cobb-Douglas Production Function incorporating anticipate, adapt, perceive, and respond.	$CR = A^{\rho} + AD^{\beta} + P^{\gamma} + RD^{\phi}$ where: CR = Collective resilience A = Anticipate AD = Adapt P = Perceive RD = Respond $\rho, \beta, \gamma, \phi$ = Weights representing relative importance
Resilience Index (RI) - Fast Damage	Measures how quickly the system is damaged.	$RI_F = \frac{R_{pd} - R_o}{t_{pe} - t_e}$ where: R_{pd}= Post-damage resilience R_o= Original resilience pe = Time to peak event t_e= Event start time
Resilience Index (RI) - System Degradation	Indicates how low the system is degraded.	$RI_L = R_o - R_{pd}$
Resilience Index (RI) - Degradation Duration	Represents how extensive (in hours) the system is degraded.	$RI_E = t_r - t_{pe}$

Resilience Index (RI) - Recovery Promptness	Specifies how promptly the system recovers.	$$RI_P = \frac{R_{pr} - R_{pd}}{t_{pr} - t_e}$$ where: R_{pr}= Post-restoration resilience t_{pr}= Time of post-restoration
Area of the Trapezoid Affected (Disaster Area)	Represents the area of the trapezoid affected from the beginning of the event t_e until post-restoration t_{pr}.	$$Area_{op} = \int_{t_e}^{t_{pr}} F_A(t)dt$$ where: $F_A(t)$= Failure area function
Time Series Analysis-Based Metrics	Provides a relationship between loss of load frequency (LOLF), energy not supplied (ENS), loss of load expectation (LOLE), capacity margin, and storm frequency/intensity.	-
Loss of Load After Disasters	Evaluates power system resilience based on loss of load after disastrous events.	-
Metrics for Microgrids	I. Metric-K: Measures the expected number of lines outages. II. LOLP: Measures loss of load. III. EDNS: Measures expected demand not supplied. IV. Metric-G: Measures grid recovery difficulty.	-
System Component Availability	Captures time and performance-related properties of the system before and after disasters using steady-state availability and event time.	Evaluated by multiplying the ratio of availability and the natural logarithm of recovery time.

An accurate extreme weather model is crucial for identifying the propagation and potential impact of extreme events. The objective of such a model includes evaluating return levels, appropriately scaling data, recreating historical events, utilizing disaster maps, and projecting 'worst-case' scenarios. Table 4 provides the extreme event model

Table 4. Extreme event model

Threats	**Approach**	**Model**
Hurricanes	Relative weighting of the event likelihood	$w_x[p(x)]$
Windstorm and floods	Return level using GEV theory	$\hat{x}_r = \hat{\mu} + \frac{\hat{\sigma}}{\hat{\xi}}[(-\log(1 - r^{-1}))^{\hat{\xi}} - 1]$
Windstorm	Scaling-up of data to observed maxima	$I_T(x) = \frac{I_t(x) \times \hat{I}_O(max)}{I_r(max)}$
Windstorm and thunder	Multiplicative factors of failure rate for different weather scenarios	$f(nt, wg) = \exp(0.0011\, nt + 0.0275wg)$
Drought	Climate model-emission scenarios based on the climate moisture index	$CMI = \frac{P - PET}{P}; -1 \leq CMI \leq 1$
Windstorm	Temporal profile of a historical windstorm	$p_{kj}^{\hat{f}} = \int_{\hat{f}_j}^{\hat{f}_{j+1}} g_k(\hat{f}).d\hat{f}$

Floods	Spatial flood probability distribution functions	$E\left(N(t+h)-N(t)\right)=\int_{t}^{t+h} v(u)du$
Windstorm and lightning	Generation and randomization of HILP event using Nonhomogeneous Poisson processes	$LI_l=\frac{N_{g,l} \cdot I_l \cdot I_{ms,l}}{D}$
Lightning	A probabilistic lightning model integrating intensity, ground flash density, and lightning peak current plus its associated maximum steepness	$P_l=P\left(D_{(x_{0,l},y_{0,l})-L}\right)P(N_{g,l})P(I_l)P(I_{ms,l}\|I_l)$
Hurricanes	Poisson probability distribution	$P(h)=\frac{\exp(\lambda)\times\lambda^h}{h!}$

Numerous studies have generated the failure models for the system components as shown in Table 5

Table 5. Fragility models for different power system components reduced to univariate regression models

Component	Method	Fragility model
Transmission Towers	Regression analysis of wind-related tower failure	$\frac{1}{1+\exp(9.035-0.153w)}$
Transmission lines	Structural modeling of components failure states under dynamic wind loading	$\frac{1}{1+\exp(13.476-0.293w)}$
Transmission towers		$\frac{1}{1+\exp(6.665-0.073w)}$
Distribution lines	Homogeneous and local fragility curves form downscaled maximum 1m gusts within a 6-hour duration of the fault	$1.25\times10^{-16}w^{10.051}$
Transmission lines at 132kV	Regression analysis of failure rates at two voltage ratings and wind gusts within a 3-hour window	$1-\exp\left[-\frac{1}{1+\exp(13.741-0.289w)}\right]$
Transmission lines at 275kV		$1-\exp\left[-\frac{1}{1+\exp(13.402-0.250w)}\right]$
Substations	The product of substation failure probability and flood scenario probability	$\frac{p_{kj}^{\hat{f}}}{12}(5w-1)$
Overhead contact lines	Cumulative distribution of lightning intensity related failures	$\frac{1}{1+\exp(12.115-1.180\ln(w))}$
Distribution transformers	Assessment of probability distribution of historical components failure due to wind intensities	$2\times10^{-7}\exp(0.0834w)$
Distribution lines		$8\times10^{-12}w^{5.173}$
Distribution poles		$10^{-4}\exp(0.042w)$
Transmission tower-overhead line system	Regression fit method based on probabilistic demand	$\frac{1}{1+\exp(50.527-1.351w)}$

	analysis of wind-related failures	
Substations	Flood depth and substation failure correlation	$\frac{1}{1+\exp(4.528-2.089w)}$

System response modeling is a crucial factor in assessing power system resilience, particularly concerning "Recovery." The Time-to-Repair (TTR) model is used to evaluate the duration required to repair a component and return it to its normal state. This model is influenced by the parameters of extreme events and generally the time taken is exponentially increased with the event intensity. Numerous TTR models had been reviewed as shown in Table 6.

Table 6. TTR model

Event	**TTR model**	**TTR_{norm} and Scale Parameters**
Wind	$\begin{cases} TTR_{norm} & w(t) \leq 20m/s \\ k \cdot TTR_{norm} & w(t) \geq 20m/s \end{cases}$	$TTR_{norm} = \begin{cases} Lines & 10\ h \\ Towers & 50\ h \end{cases}$ $k = 2$
Wind	$TTR_{norm} \cdot \begin{cases} 1 & w(t) < 20m/s \\ 1 + \frac{k(w(t) - w_{critical})}{TTR_{norm}} & w(t) \geq 20m/s \end{cases}$	$TTR_{norm} = \{Towers \quad 48\ h$ $k = 2$
Flood	$TTR_{norm} \cdot \begin{cases} 1 & w(t) < 138mm & intense \\ 1 & w(t) < 280mm & prolonged \\ k & w(t) \geq 138mm & intense \\ k & w(t) \geq 280mm & prolonged \end{cases}$	$TTR_{norm} = \begin{cases} Power\ plant & 10\ h \\ Substations & 20\ h \end{cases}$ $k = 2$
Wind	$\begin{cases} TTR_{norm} & w(t) \leq 20m/s \\ k_1 \cdot TTR_{norm} 20m/s \leq w(t) \leq 40m/s \\ k_2 \cdot TTR_{norm} & w(t) \geq 40m/s \end{cases}$	$TTR_{norm} = \begin{cases} Lines & 10\ h \\ Towers & 50\ h \end{cases}$ $k_1 \sim U[2,4]\ and\ k_2 \sim U[5,7]$
Flood	$702.72d^2 + 314.95d + 1.99$	k is the slope of the regression function of intensity and repair duration
Lightning and flood	$TTR_{norm} k_1 k_2 \times \begin{cases} 1 & , & w(t) < 8m/s \\ 1 + \frac{k(w(t) - w_{critical})}{TTR_{norm}}, & & w(t) \geq 8m/s \end{cases}$	$k_1 = \begin{cases} \frac{\overline{TTR}_{weekday}}{\overline{TTR}} & weekday \\ \frac{\overline{TTR}_{weekend}}{\overline{TTR}} & weekend \end{cases}$ $k_2 = \begin{cases} \frac{\overline{TTR}_{7-17}}{\overline{TTR}} & 0700 - 1700hrs \\ \frac{\overline{TTR}_{17-7}}{\overline{TTR}} & 1700 - 0700hrs \end{cases}$
Generic	$-TTR_{norm} \times \ln(k)$	$TTR_{norm} = \{Lines \quad 6\ h$ $k \sim U(0,1)$
Flood	$T + 168$	

Figure 11 presents the overview of optimization in resilience enhancement studies.

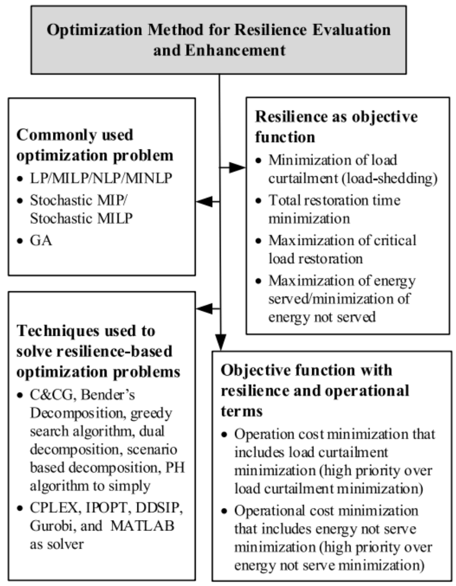


Figure 11. Overview of optimization in resilience enhancement studies

After determining the current resilience level of the power system, appropriate enhancement strategies are necessary for improvement. Resilience enhancement strategies can be categorized into infrastructure, operational, and organizational approaches. Infrastructure strategies aim to strengthen transmission and distribution systems through grid expansion plans, providing long-term resilience against extreme events, though they often require significant investment. On the other hand, operational strategies focus on optimizing grid operations and implementing flexible solutions, offering a more time- and cost-efficient means of improving resilience. Table 7 summarized the current practice of resilience enhancement strategies.

Table 7. Current practice of resilience enhancement strategies

Infrastructure	**Operational**	**Organization**
• Undergrounding lines • Constructing redundant corridors and interconnectors • Doubling transmission circuits • Upgrading poles and towers' strength • Elevating substations • Substation relocation and line rerouting • Installing backup generators and mobile transformers • Optimal location of battery storage units with grid-forming inverters and black start capabilities	• Reconfigure the network and form microgrids • Rapid load restoration and emergency response • Situational awareness through effective grid monitoring systems • Preventive response • Conservative interconnector limits • Enhanced special protection schemes • Enhanced demand and generation forecasting • Improve generator and system modeling capabilities	• Develop protocols for encrypted communications • Mandate technical standards for power provision • Effective system restoration administrative and communication processes • Effective spare parts and repair crew management • Regulation and design standard upgrade • Devising and implementation of an effective Outage Management System

• Integrating energy systems • Improve firmware • Procurement of regional frequency control ancillary services • Enhance reservoir capacity • Increase dam crest height • Build upstream sediment control structures • Strengthen river embankment • Relocate powerhouse to less prone region	• Coordinated and appropriately tune generator control responses • Increased multiple fault ride-through and active power recovery capabilities • Revise operating regimes • Decentralized protection and control	• Conducting preparedness planning and training • Managing vegetation • Participation in mutual assistance groups • High compliance with inspection protocols • Securing emergency fuel contracts • Supplying logistics to staging areas • Increased reginal cooperation on system interconnection • Plan energy mix based on potential future vulnerabilities • Create a regulatory framework for enforcing resilience enhancement • Incentivize the implementation of resilience measures

Tran Gia Huy

Topic: Research On The Influence Of Spatial And Temporal Aspects In Forecasting

Research Period: June 3, 2024 – August 24, 2024

Abstract: This research investigates the influence of spatial and temporal aspects in forecasting, with a focus on applications in various domains. By examining the interplay between spatial and temporal data, the study aims to improve the accuracy and reliability of predictive models. Utilizing advanced statistical techniques and machine learning algorithms, the research explores how spatial heterogeneity and temporal dynamics impact forecasting outcomes. Case studies in photovoltaic (PV) power generation, weather prediction, and traffic flow analysis are used to illustrate the benefits of incorporating spatial-temporal factors. The findings highlight that integrating spatial and temporal dimensions can significantly enhance forecast precision, reduce errors, and provide more actionable insights. This research contributes to the growing body of knowledge in spatial-temporal analytics and offers practical guidelines for implementing these techniques in real-world forecasting scenarios. The results underscore the importance of considering both spatial and temporal variability to achieve more robust and accurate predictions, ultimately supporting better decision-making in diverse fields.

Key Findings: This report discusses how to forecast photovoltaic (PV) energy, with a focus on analyzing the impact of spatial and temporal data on the accuracy of test results. It outlines the steps involved in making a forecast and explains the operation of the forecasting model, specifically the Long Short-Term Memory (LSTM) model. In theory, forecasting with actual data can be divided into two scenarios: one where only historical data is used, and another where the correlation between different PV systems is consistently leveraged to make predictions. The report aims to demonstrate that incorporating data in a spatial-temporal format significantly enhances the accuracy of the forecasts.

The data used in this study consist of time series of the measured PVs generation of a set of power plants located in Chiayi, Taiwan. The data collected includes 9 power plants site. The data cover a period of 1 year starting from (2021-01-01 00:00:00) to (2021-12-31 23:00:00) with a resolution of 1 hour. The data quality has been tested and the inconsistencies have been removed (i.e. Cleaning erroneous data, dealing with missing values). Each file includes the first column is time divided by hours, the second column is power (kW).

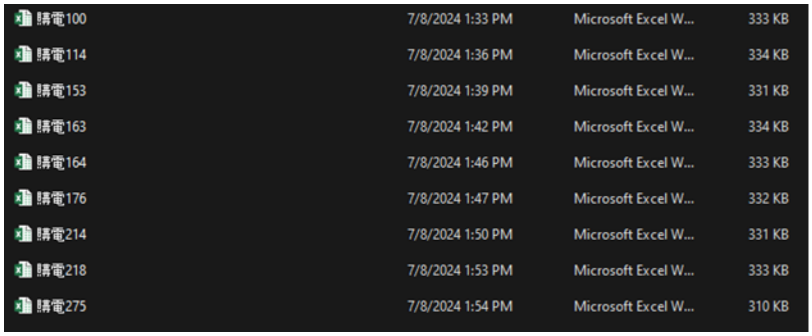


Figure 12. The input data in this case study

Purpose of case study: To prove that when spatial is involved in the forecast, the quality of the forecast results will increase . Use LSTM model to perform reporting for two cases and compare the result:

- Case 1: Only use historical data of site 100 as input to perform reporting
- Case 2: Use all other Sites as input to forecast Site100

Case 1: To respect the confidentiality required by the data providers, the data were normalized using the maximum observed production for each power plant. The resulting data are ranged between 0 and 1 allowing a more suitable format for the prediction models as well as easy interpretation of forecasting errors. Use min-max scaling to convert the values to the dimensionless party. Then we put the normalized data into the Long Short Term Memory (LSTM) model to start the analysis. Using 80% data to training set and the remaining 20% for testing set.

Figure 13. Data processing process of case 1

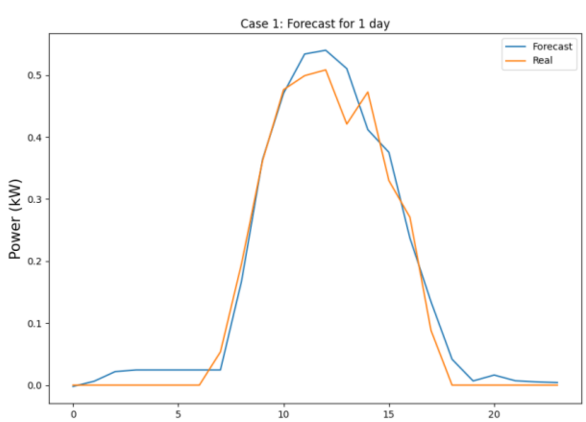


Figure 14. Forecast results for 1 day of case 1

```
Train MAE: 0.03781545218455713, Train RMSE: 0.06330022237957854
Test MAE: 0.03739393235039904, Test RMSE: 0.05977181610516564
```

Figure 15. Forecast error of case 1

Case 2: Because we need to consider the relationship between PV Sites to select PV sites that have high correlation with Site 100. Using the Pearson formula to compute the correlation coefficient between PV stations based on their power output data.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

where

- n is sample size
- x_i, y_i are the individual sample points indexed with *i*
- $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ (the sample mean); and analogously for $\bar{y}$.

Based on the correlation index, we will select PVs with high correlation and ignore PVs with low correlation. General guidelines:

Very Strong Correlation: r ≥ 0.9

Strong Correlation: 0.7≤ r < 0.9

Moderate Correlation: 0.5 ≤ r <0.7

Weak Correlation: 0.3 ≤ r < 0.5

Very Weak or No Correlation: r < 0.3r

With r: is the correlation

For this case study, we choose sites with very strong correlation.

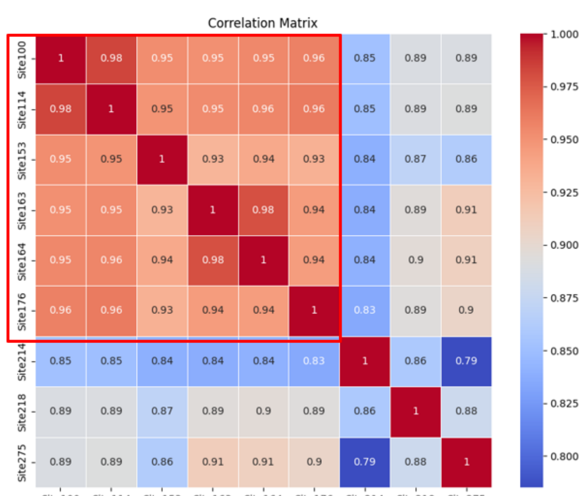


Figure 16. Correlation matrix between all sites

Choosing the correlations between Site 100 and other Sites are above 0.9 , using the site: Site100 (subject needs forecasting), Site114 (0.98), Site153 (0.95), Site 163 (0.95), Site 164 (0.95), Site 176 (0.96). After selecting the Sites with high correlation to Site 100, we pass the data through normalization with min-max scaling. Then we put the normalized data into the Long Short Term Memory (LSTM) model to start the analysis. Using 80% data to training set and the remaining 20% for testing set.

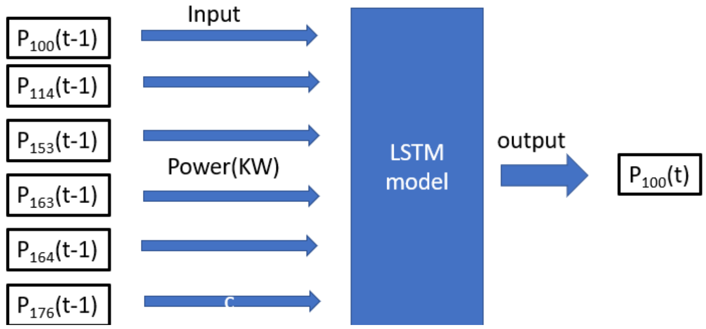


Figure 17. Correlation matrix between all sites

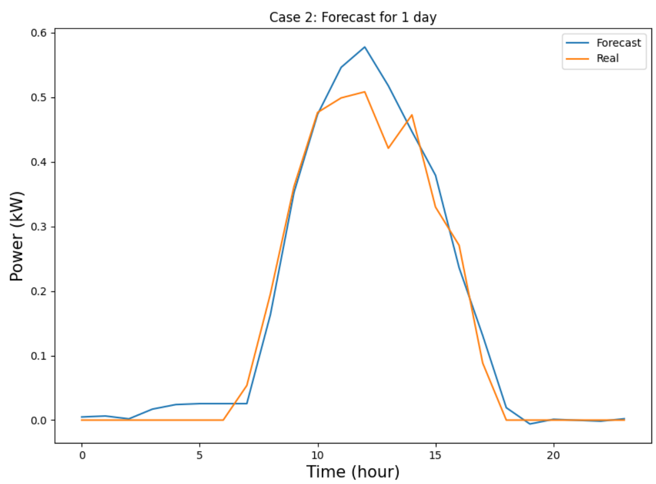


Figure 18. Forecast results for 1 day of case 2

```
Train MAE: 0.029914107362191317, Train RMSE: 0.052133780683152185
Test MAE: 0.024615692028131984, Test RMSE: 0.041706265043875555
```

Figure 19. Forecast error of case 2

Table 8. Compare the results of 2 cases

	CASE 1	CASE 2
Train MAE	**0.03781**	**0.02991**
Train RMSE	**0.06330**	**0.05213**
Test MAE	**0.03739**	**0.02462**
Test RMSE	**0.05877**	**0.04170**

Huynh Minh Trieu

Topic: Resilience of The Power System in Extreme Weather

Research Period: June 3, 2024 – August 24, 2024

Abstract: This report provides an overview of the recovery process of the power system (towers, distribution lines, transmission lines) when faced with extreme events, such as severe weather: storms, high winds, floods, lightning strikes. Explore models to assess the damage potential of towers and lines. Resilience curves, metrics to assess the recovery process and repair time of components. Measures to enhance resilience and challenges. Finally, there are illustrative examples of the resilience of the power system to lightning strikes on lines and to wind storms in the Great Britain.

Key Findings: Tower failure probability model, line failure probability model and resilience curve.

Formulas to determine the resilience of the power system in each case and a multiphase resilience evaluation process.

The average tower repair time when encountering a wind storm is 49 hours, the average line repair time when encountering a wind storm is 10 hours.

Resilience evaluation indicators: Energy served, Demand served, Load of load probability, Loss of load expectation...

Measures to enhance resilience: infrastructure, operational, organizational. Infrastructure: undergrounding lines, constructing redundant corridors and interconnectors... Operational: reconfigure the network and form microgrids, rapid load restoration and emergency...Organizational: develop protocols for encrypted communications, mandate technical standards for power provision, ...

In the illustrative example of the resilience of a power system after a lightning strike, the results are as follows: the maximum lightning current is 3.5 kA and results in a phase-to-ground short circuit, the total time from the start of the event until the frequency is restored is approximately 5 minutes, the eventual probability of failure was computed as 0.0033%, the system had a single interruption that lasted for about 40 minutes leading to unserved energy of 270 MWh. Enhancement: the control system software for the wind farm has been updated, new sector communication guidelines issued, protection system settings for the affected category of trains revised, and the Low-frequency Demand Disconnection (LFDD) services improved especially concerning critical demand.

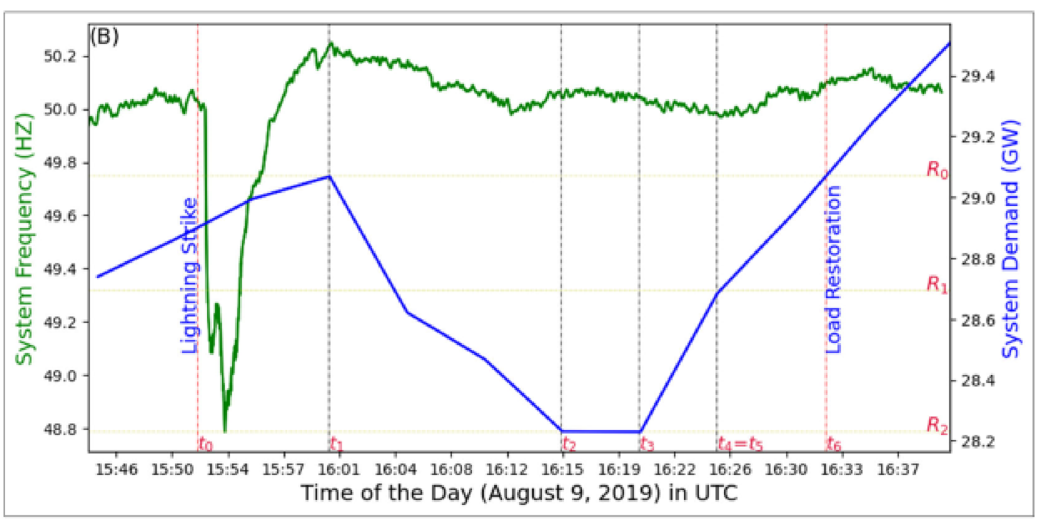


Figure 20. Great Britain's power system demand and frequency on August 9, 2019 focuses on the lightning incidence (Blue line is system demand GW, green line is system frequency Hz)

Table 9. Resilience evaluation by several indicators from lightning events in Great Britain

Indicator	Value
Loss of load frequency	1 occurrence/day
Loss of load expectation	0.7 h/day
Energy not supplied	270 MWh/day
Energy index of unreliability	1.9%
Energy served	98.1%
Demand served	97.1%
Energy not supplied	1.9%
Value of Lost load	£5 Million
How fast resilience drops	34 MW/minute
How low resilience drops	2.9%
The extent of the degraded state	5 minutes
How promptly the system recovers	70 MW/minute

In the illustrative example of the resilience of the power transmission system during a wind storm, the results are: the maximum failure probability of lines and poles in the six regions is about 0.07% at a wind speed of 15 m/s. At lower wind speeds (= 40 m/s), the strengthening is very effective, achieving a resilience improvement of almost 100%. At higher wind speeds (= 60 m/s and 50 m/s), the response measures have a greater impact than the contingency measures.

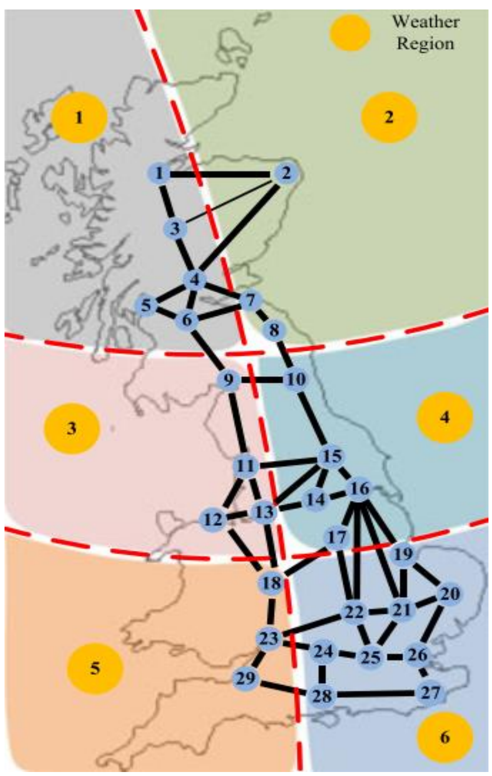


Figure 21. Weather regions of Great Britain

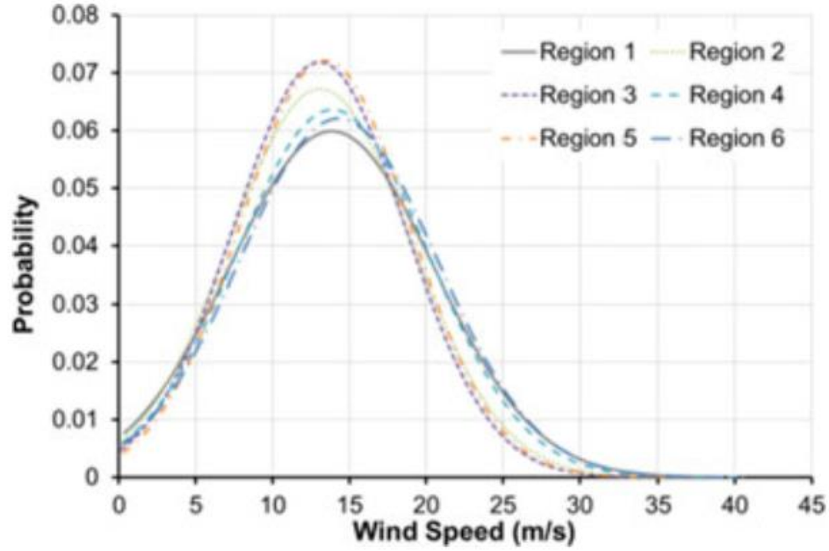


Figure 22. Probability density function of regional wind profiles with maximum speed =40 m/s

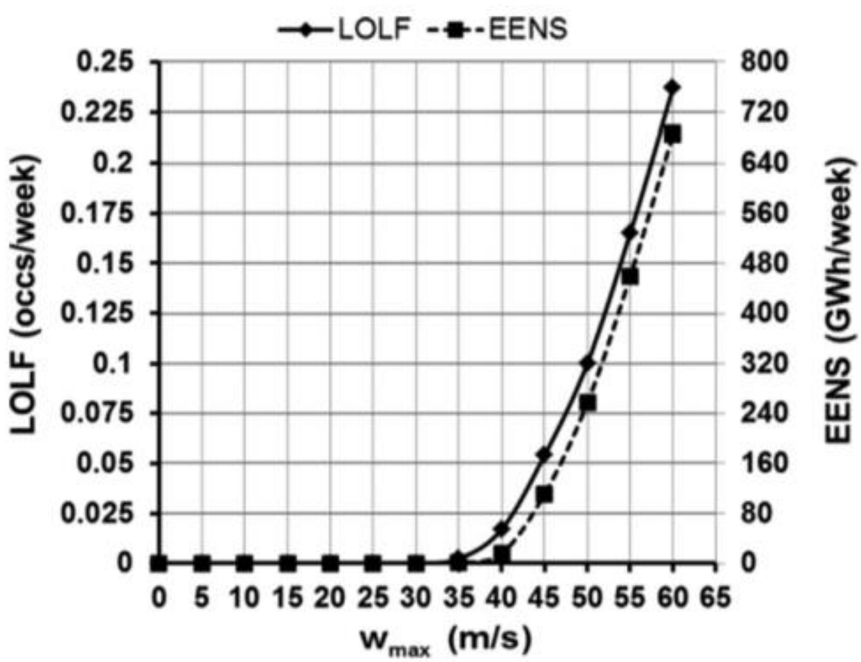


Figure 23. Influence of wind on LOLF and EENS as a function of w_max of each wind profile for the base case

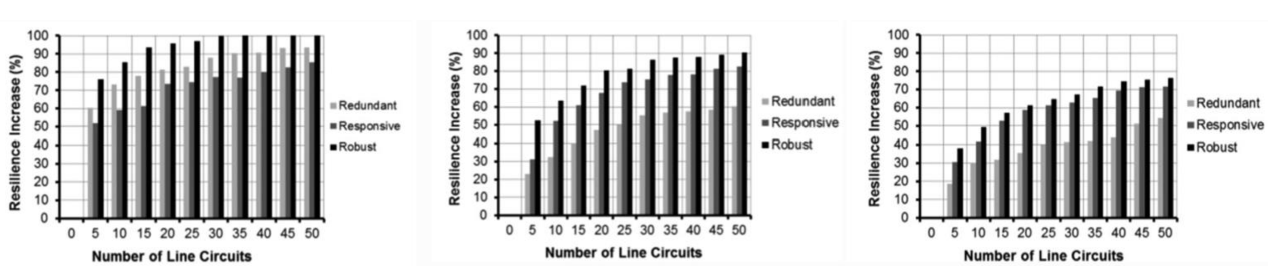


Figure 24. The effect of enhancing resilience for different wind levels is:

a) 40 m/s, b) 50 m/s and c) 60 m/s, respectively

Bui Khanh Hao

Topic: Campus Microgrid Projects and Experience

Research Period: June 3, 2024 – August 24, 2024

Abstract: Many universities have adopted microgrid systems due to their reliability, security, flexibility, and reduced dependence on the main grid. The microgrids of the systems in the sample campuses face challenges related to the instability of the electricity product due to meteorological conditions, as the output of renewable energy sources such as solar and wind is completely dependent on the details and priorities of the microgrid size. In this report, we will give you an overview of the microgrid and some microgrid systems at the university.

Key Findings: The simulation platform utilized for the current study is PSCAD.

First, the microgrid is operated in the islanded mode. The system is initiated from no-load and at 1sec, the Watt center critical load is activated followed by critical loads of Calhoun courts and Cooper library at 2s and 3s respectively. The response of the microturbine for the fixed- speed and variable-speed mode are shown in figure 25 and figure 26.

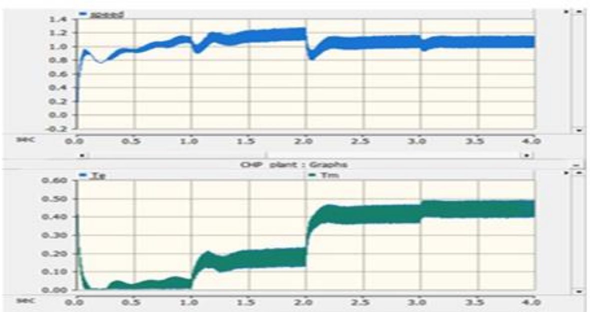


Figure 25. Fixed-speed operation

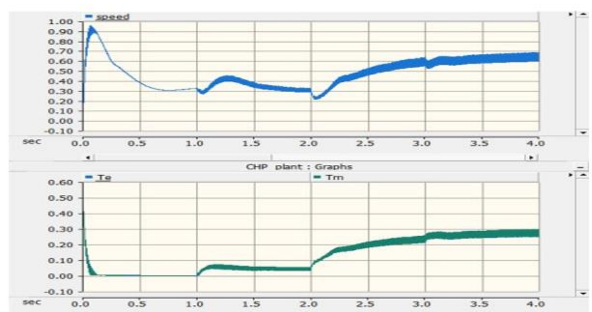


Figure 26. Variable-speed operation

It is observed from figure 25 that the microturbine operates at a fixed speed of 1p.u. even in the no-load scenario (Te= 0) and whenever there is a load variation, the speed again recovers back to 1p.u.

It is observed from figure 26. that the CHP plant operates at a minimal speed of 0.3p.u with no-load. This minimum speed is maintained as the operation of the CHP plant below a certain speed is not recommended from the economic point of view. It is observed that the CHP plant now tracks the load variations instead of a fixed-speed operation.

The microgrid is initially operated in the grid-following mode. At 0.8s, the microgrid is commanded to go into the islanded mode. At 3s, the system is commanded to go back to the grid-connected mode from the islanded mode.

It is observed from figure 27 - 28 that the transition from the grid connected mode to the islanded mode and the islanded mode to the grid connected mode are smooth.

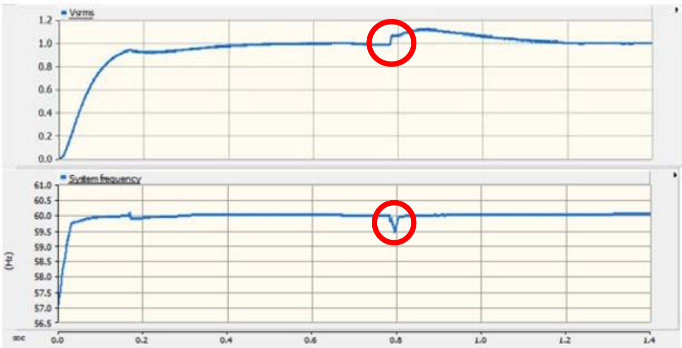


Figure 27. PCC voltage and frequency response during transition from grid connected mode to islanded mode

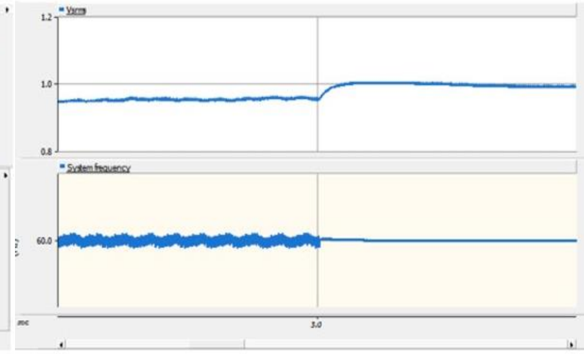


Figure 28. PCC voltage and frequency response during transition from islanded mode to grid-connected mode

For this test, a three-phase to ground fault is simulated on the IEEE bus connected to the microgrid and the worst-case scenario, a 3-phase fault is simulated on the PCC bus at 3s. The system response is shown in two Figure. It is observed that voltage and frequency response meet the IEEE 1547.4 requirements.

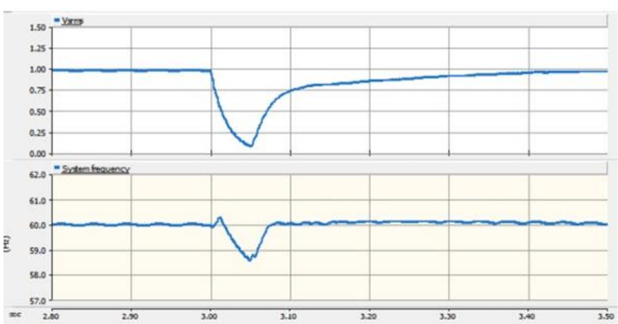


Figure 29. PCC voltage and frequency during a fault at the connected IEEE bus

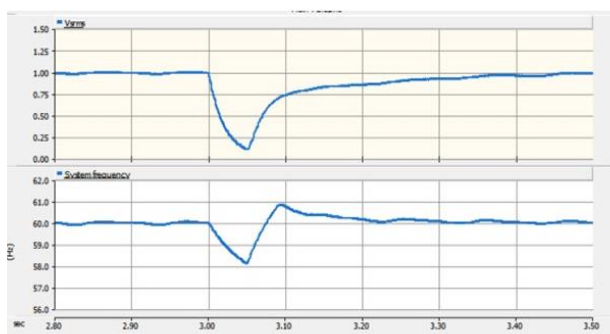


Figure 30. PCC voltage and frequency during a fault at the PCC bus

Table 10. Voltage and frequency ride through requirement

Voltage and frequency magnitude (p.u)	**Time after fault (s)**
0.45-1.2	≤ 0.16
0.7-1.1	≤ 2
0.95-1.05	≤ 10

Lam Hong Phuc

Topic: The method and control technologies to reduce the impact of low inertia on power system with a high penetration of renewable power generation

Research Period: June 15, 2024 – August 27, 2024

Abstract: To meet the growing energy demand while ensuring the reduction of greenhouse gas emissions, the use of large-scale renewable sources (LsREP) has been developing at a rapid pace. However, with the increasing proportion of LsREP, frequency stability needs to be considered due to the asynchronization between conventional generators and inverter-based generators. Furthermore, the sharp decrease in dynamic energy storage due to low minimum rotating mass leads to low inertia. This research briefly presents the causes of frequency instability due to low inertia, and then proposes optimization control strategies.

Key Findings: This report introduces the fundamental problem of low system inertia in power systems due to the high share of renewable energy sources. The dynamic model of each component in the system will be explained and derived. Based on theory, a simulation model is built to test and evaluate the effectiveness of the system. The report also presents an overview of several methods for improving control systems using methods such as virtual synchronous generators or energy storage. The quality of the system and the stability of the control methods are analyzed and evaluated through the system response.

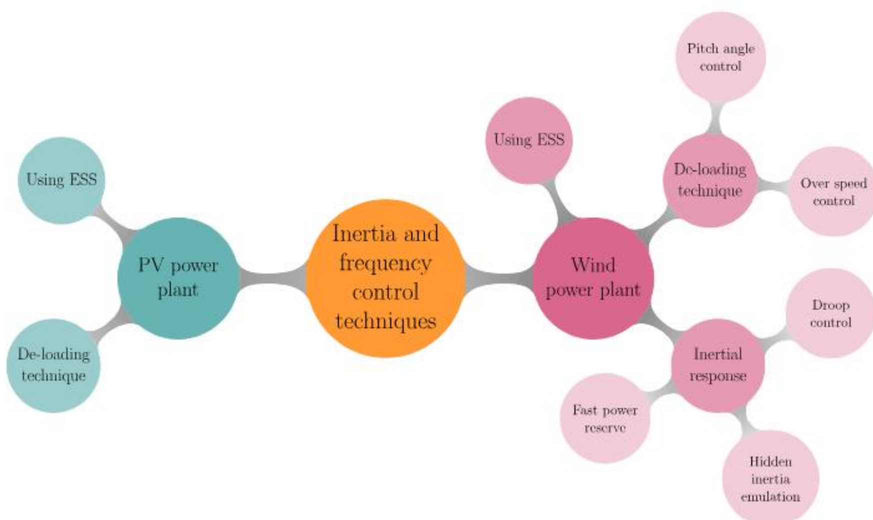


Figure 31. Control methods reduce the influence of low system inertia on the power system.

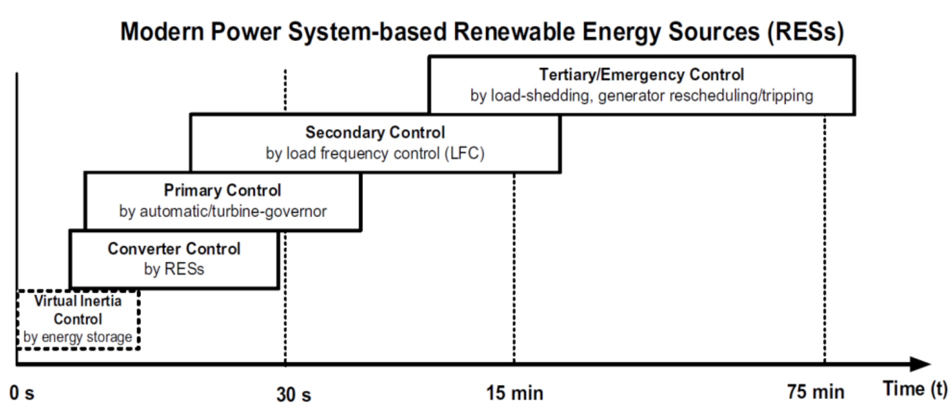


Figure 32. The timescale of frequency dynamic control for modern power systems dominated by power electronics-based DGs/RESs

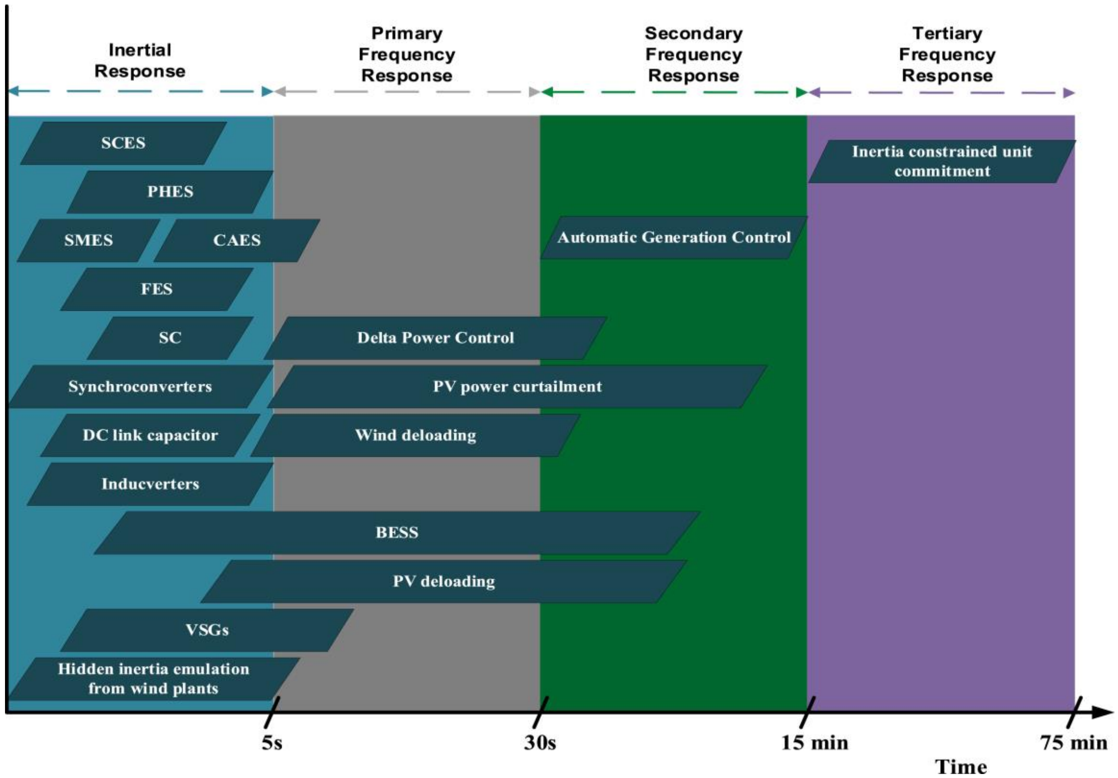


Figure 33. Comparison of response time of different frequency control technologies

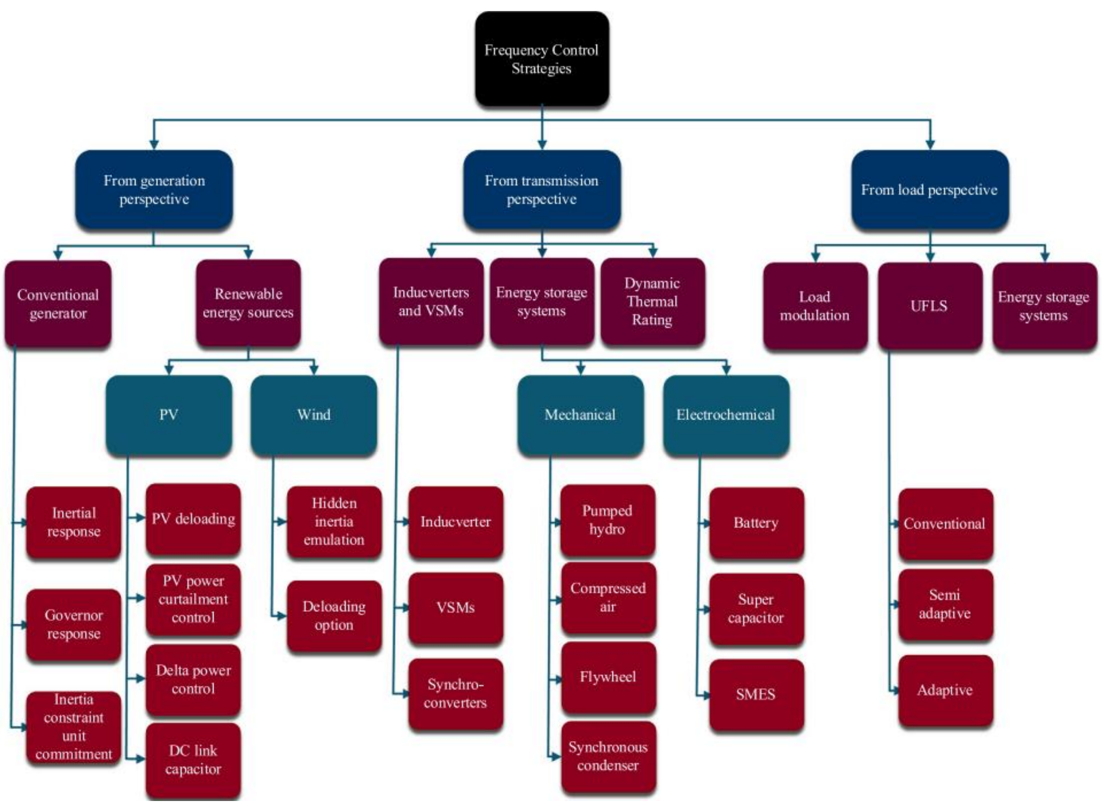


Fig 33. Frequency control strategies in low-inertia grids.

Nguyen Thuy Phuong

Topic: Research To Improve The Controller And Simulate The Averaged Three-Phase Voltage Source Converter System

Research Period: February 2, 2024 – July 31, 2024

Abstract: The integration of renewable energy sources, such as solar photovoltaics, wind power, and battery systems, is becoming increasingly popular in the worldwide power grid. These technologies are called Inverter-based Resources (IBRs), and they are essential to the transition to sustainable energy in the future. The Voltage Source Converter (VSC) is an important component of the grid since it connects and stabilizes the many energy inputs. This research explores the fundamental principles of Voltage Source Converter systems. The report also presents a method for improving VSC control systems through the addition of a power control loop. In order to better understand its operational dynamics and performance characteristics, a simulation model based on the Averaged VSC model is developed in MATLAB for observation and assessment.

Key Findings: This report introduced the fundamental principles of Voltage Source Converter systems. The dynamics model of each component in the system will be explained and derived. Then the detailed process for designing its controlled system is also presented. Based on the theory, a simulation model is developed to check and evaluate the system's effectiveness. The report also presents a method for improving VSC control systems by adding a power control loop. Finally, two simulation cases are implemented to compare the results of the system when with and without the power control loop.

In this research, I only focus on improving the controller by adding the power control loop. To compare the results of this control system, the simulation is implemented with 2 cases, with and without the power control loop. In case 1, without the power control loop, the reference currents are defined by mathematic equations as:

$$\begin{cases} i_{dref-pu} = \dfrac{P_{sref-pu}}{V_{sd-pu}} \\ i_{qref-} = -\dfrac{Q_{sref-pu}}{V_{sd-pu}} \end{cases}$$

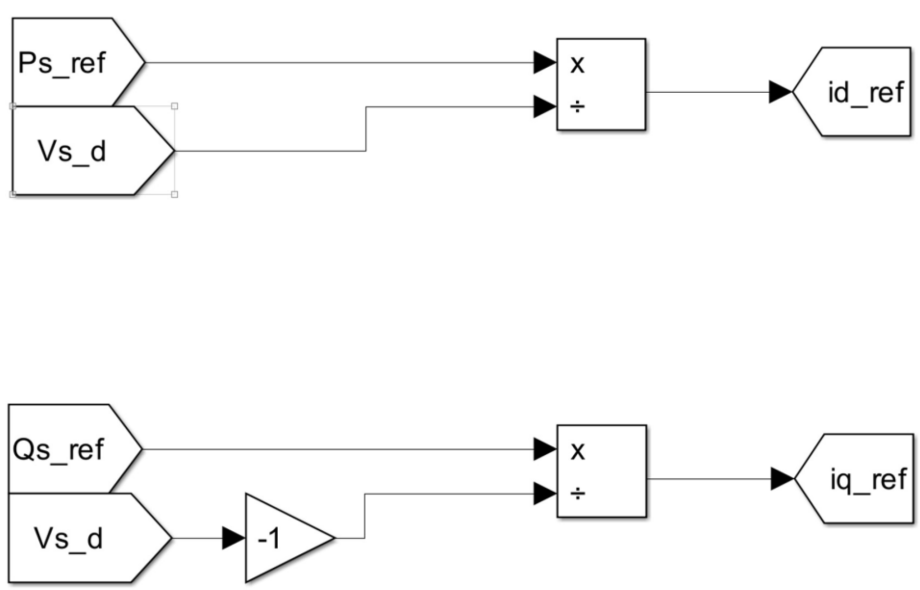


Figure 34. Structure of the reference current generator in case 1

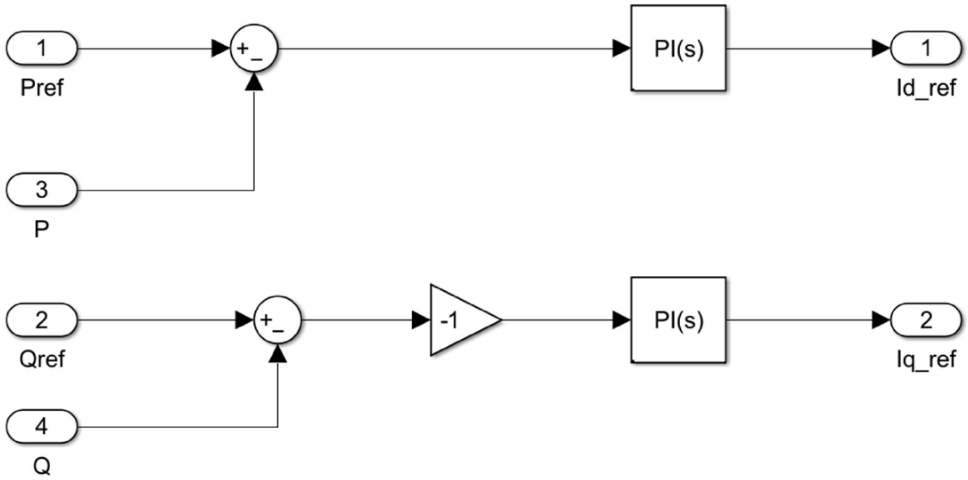


Figure 35. Structure of power control loop in case 2

The remaining parameters of the model are calculated using MATLAB according to the theories discussed above.

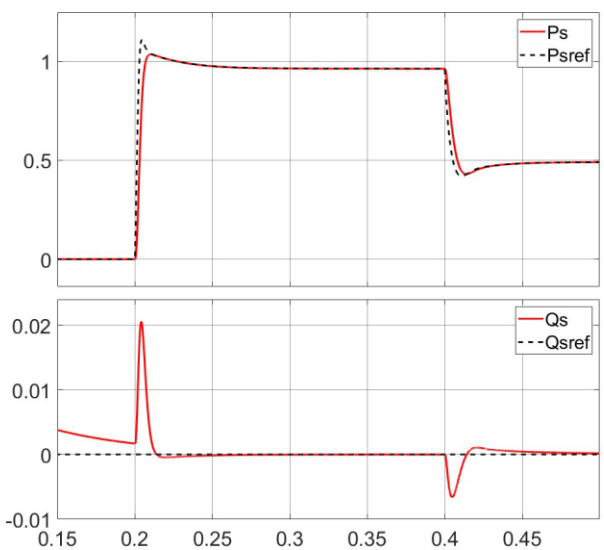


Figure 36. Power in case 1

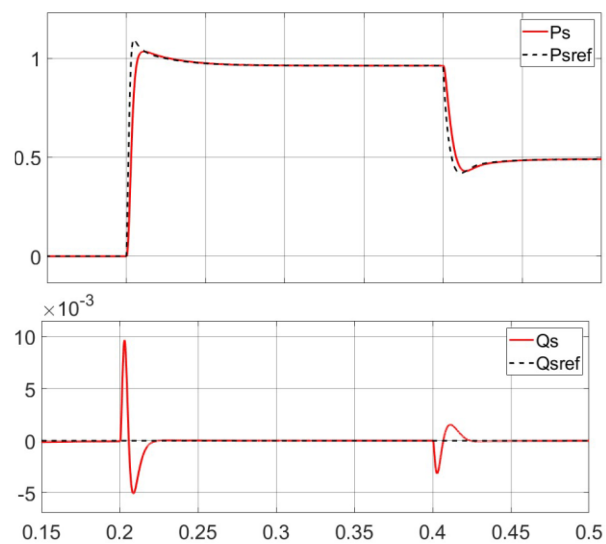


Figure 37. Power in case 2

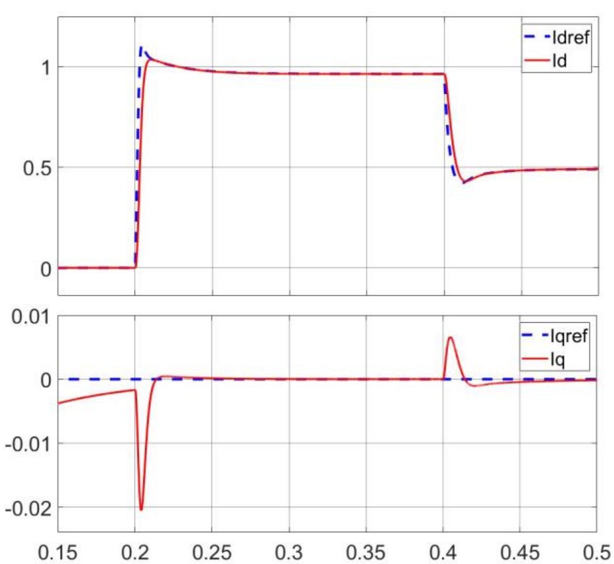


Figure 38. Current in case 1

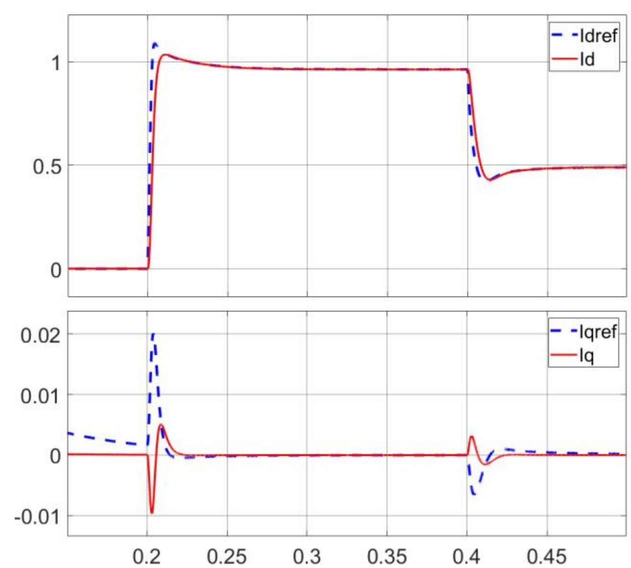


Figure 39. Current in case 2

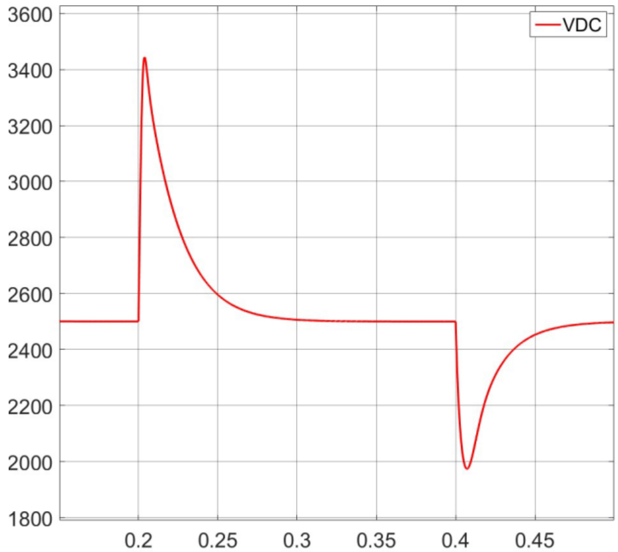


Figure 40. DC voltage in case 1

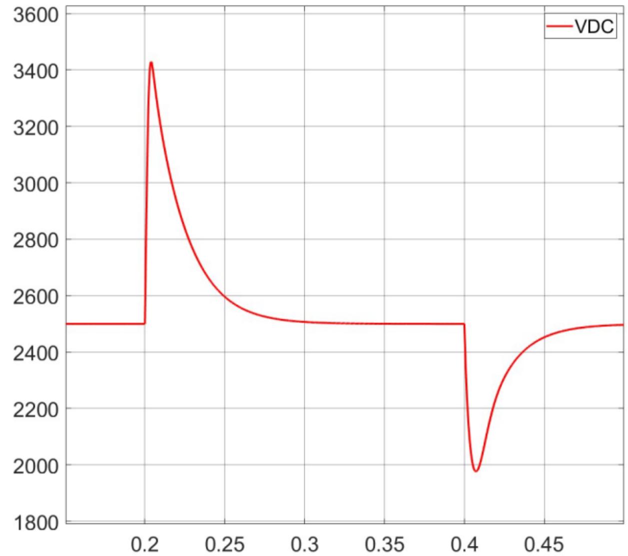


Figure 41. DC voltage in case 2

Figures 36 and 37 show that in case 2, the power responses have smaller overshoot than case 1, especially reactive power.

Figures 38 and 39 show that in case 2, the current responses have smaller disturbances than case 1, especially I_d

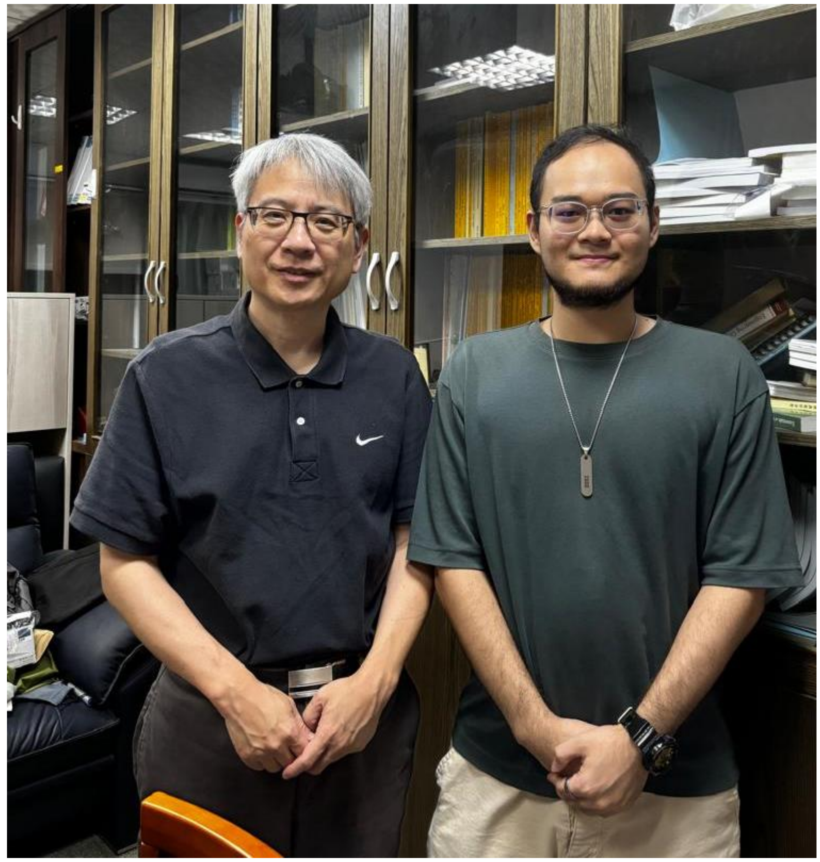
Figures 40 and 41 show that the DC voltage responses are almost the same in two cases since they have two identical structures. When the DC power source changes its operating power exchanged with the VSC, the DC-bus voltage changes but it quickly returns to its operating value due to the adjustment of the DC-bus voltage control loop.

Photos Section

1. Photos of students with Prof. Wu.

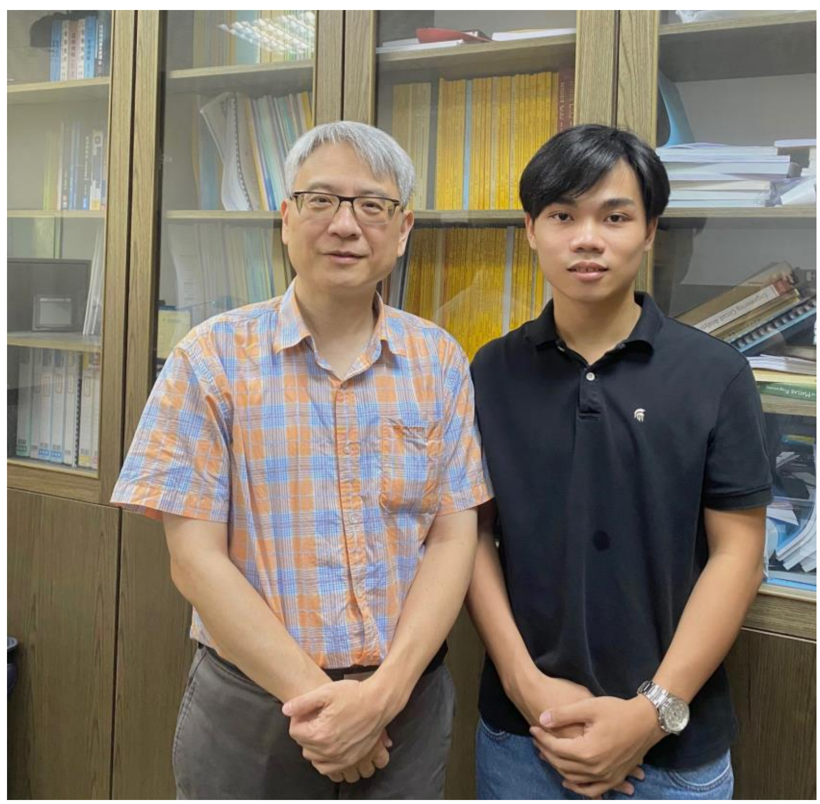
Wendy Tang

Ly Thoi Hung

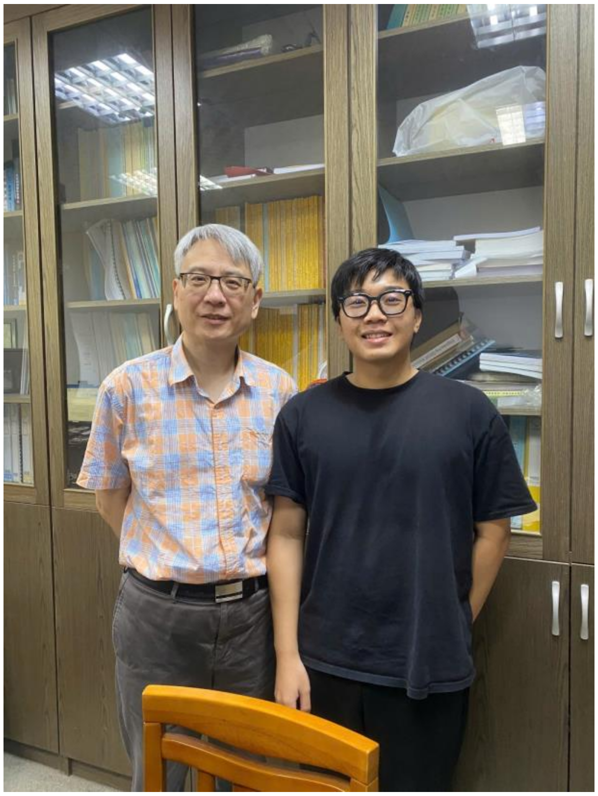


Ling Jie Qi

Huynh Minh Trieu



Bui Khanh Hao

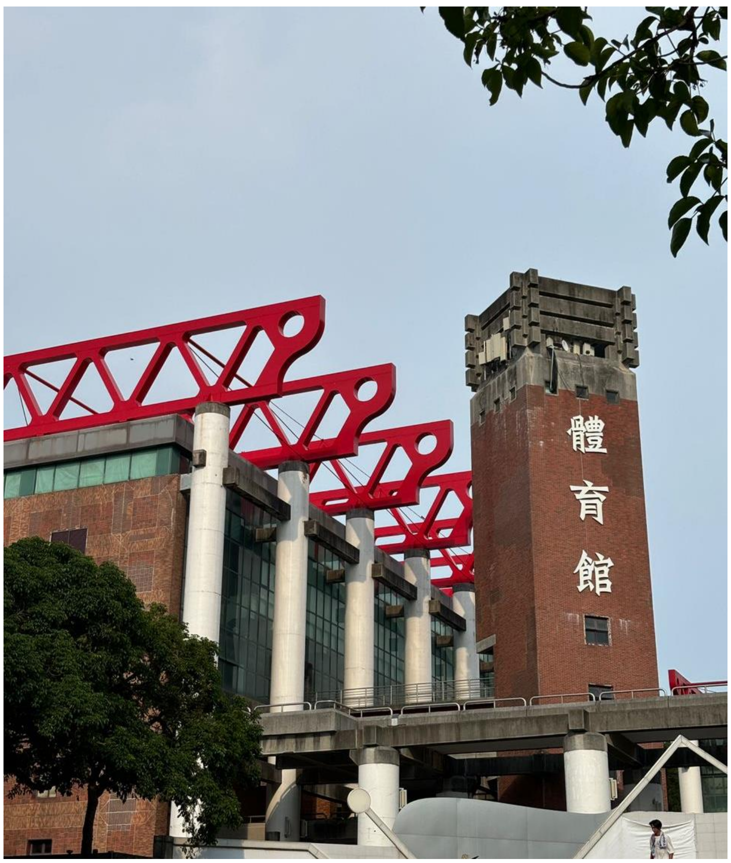


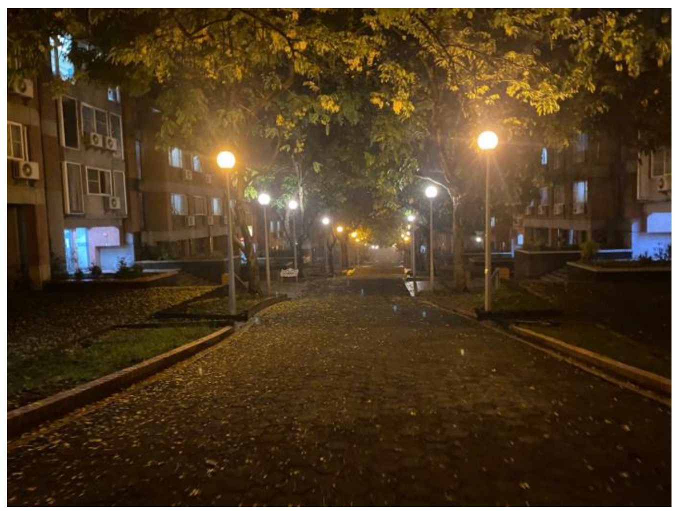
Tran Gia Huy

Lam Hong Phuc

Nguyen Thuy Phuong

2. Campus photos from National Chung Cheng University.


體
育
館




CCU

Experiences

WENDY TANG

First of all, I would like to express my heartfelt gratitude to Professor Yuan-Kang Wu for accepting my internship application, which allowed me to embark on an incredible journey at National Chung Cheng University (CCU) in Taiwan. This opportunity has been a gateway to numerous new experiences, starting right from the application process.

Living on the CCU campus was an enriching experience. Despite initial concerns, the language barrier posed no significant issues. The campus facilities were remarkably advanced and convenient, providing a stark contrast to those at my home university in Malaysia. For instance, access to dormitories and academic buildings was managed via access cards, adding a layer of security and convenience. Additionally, electricity bills were seamlessly managed through an electricity card system, which could be topped up as needed. This was a new and efficient way to handle utilities that I had not encountered before.

The campus was vibrant with numerous activities and performances organized by both students and external groups. These events offered a glimpse into the diverse cultural and artistic expressions in Taiwan. The food on campus was another highlight, catering perfectly to my taste and allowing me to savor Taiwanese cuisine.

From the very first day, the host student at CCU were exceptionally friendly and helpful. He guided me around the campus, making my initial days much smoother. My interactions with fellow students were intellectually stimulating and collaborative. We shared insights on modelling solar photovoltaic (PV) systems using MATLAB, and they offered valuable suggestions that enriched my understanding and approach to the project.

The discussions with Professor Yuan-Kang Wu were particularly enlightening. He emphasized the importance of comprehending the mathematical models underlying metaheuristic algorithms, which are crucial for our research on solar PV systems. His guidance helped me grasp complex concepts and apply them effectively to my work. The professor's mentorship extended beyond technical knowledge, fostering a deeper appreciation for the research process and the rigorous analytical thinking required in academia.

Overall, the 12-week internship at CCU from April 1 to June 22, 2024, was a transformative period filled with learning, cultural exchange, and professional growth. The welcoming campus environment, advanced facilities, engaging student activities, and the profound academic discussions collectively made this internship an unforgettable experience. I am profoundly grateful for this opportunity, which has broadened my horizons and significantly contributed to my academic and personal development.

LY THOI HUNG

My name is Ly Thoi Hung and I am from Vietnam. This is both my first time in Taiwan and my first time going abroad. My internship is only for three months, but this has been an interesting experience for me.

The scenery and the atmosphere at CCU are very nice. It is quiet and calming, with a lot of trees. The night sky here is beautiful too. The dormitory room is very spacious, comfortable and well-furnished. The dormitory staff and the school office staff are really friendly and helpful.

Professor Yuan-Kang Wu is the most distinguished scholar that I ever have had the chance to meet, let alone have discussions with. Although he is extremely busy, he still takes time to discuss with his interns with a cheerful and patient attitude while giving constructive advice. Before I met him, I could not imagine that such an important person would take so much time to care about an intern who only stays at CCU for a mere three months. For this, I am truly grateful. I have my sincerest thanks to Professor Yuan-Kang Wu for giving me the chance to experience CCU specifically and Taiwan as a whole.

LING JIE QI

My name is Ling Jie Qi, and I'm from Malaysia. This is my first time participating in an internship program at CCU, where I'll be staying for three months.

Upon arriving at CCU, I was immediately struck by the vastness of the campus and its beautiful natural surroundings. Beyond the scenic views, CCU offers a wide range of facilities that cater to my everyday needs, including a gymnasium, library, and convenient stores. As someone who enjoys staying active, the gymnasium at CCU has been a highlight for me, providing numerous options for exercise. The campus boasts facilities such as a football field, basketball courts, a gym, swimming pool, and even a golf course. Additionally, getting to Minxiong city is quite convenient, with buses running there every hour, making it an easy and enjoyable place to visit.

I have learned a great deal from Professor Wu, especially from his passion and dedication. In every discussion, he thoughtfully prepares questions that encourage me to think more deeply and approach problems from different perspectives. Whenever I find myself uncertain about the direction of my research, he kindly guides me back on track. I am incredibly grateful for this opportunity to work with him.

My lab mates have also been very friendly and helpful, offering support both in research and with everyday challenges at CCU. I've had the chance to meet many new friends from Thailand, Malaysia, Indonesia, and Vietnam. This internship has provided me with a unique opportunity to expand my international connections and grow personally and professionally. It has also given me the chance to explore Taiwan, discovering its rich culture, delicious food, and natural beauty.

TRAN GIA HUY

My name is Tran Gia Huy. I come from Vietnam. This is my first time interning in Taiwan. Although I only interned at CCU for only 3 months, it brought a very memorable experience for me.

When I first arrived at CCU, I was struck by the vast and open space of the campus. The buildings are thoughtfully designed to blend harmoniously with the surrounding environment, creating a sense of peace and connection with nature. I was particularly impressed by how CCU integrates modern architecture with lush greenery, providing a learning environment that is not only functional but also deeply inspiring. The communal areas are more than just places for socializing; they serve as spaces for relaxation and recharging after intense study sessions.

The atmosphere in my lab is incredibly welcoming, with everyone being kind and approachable. Their enthusiasm and willingness to assist me have made my experience much smoother. My lab colleagues, Mr. Tung, Mr. Thang, and Mr.Huy have been invaluable in guiding me through both research challenges and the nuances of life at CCU. Especially Mr. Thang, who helped me a lot in teaching me how to do my report. Beyond the lab, I've also made new friends from Vietnam and various other countries. Despite being an introvert, I find myself feeling at ease and embraced by this supportive community.

The most special thing to me is that the person who guided me during my internship at CCU was Professor Yuan-Kang Wu. Professor Yuan-Kang Wu is someone who has had a profound influence on me. His dedication to his work and his passion for continuous learning are truly admirable. Whenever we have discussions, his positive energy and constant smile create a relaxed atmosphere that encourages open dialogue. He frequently poses thought-provoking questions that challenge me to dive deeper into my research, helping me broaden my perspective. Additionally, his patience in providing constructive feedback and thoughtful advice has been instrumental in helping me refine my skills. I feel incredibly fortunate to have the opportunity to work alongside him and learn from his experience.

In conclusion, I would like to express my heartfelt gratitude to Professor Wu for offering me this invaluable opportunity and for his unwavering support throughout my internship. I am also deeply thankful to everyone at CCU who has assisted me along this journey. I truly hope that I will have the chance to return to CCU in the future and collaborate with everyone once again. I think what I learned here has helped me develop myself a lot.

HUYNH MINH TRIEU

My name is Huynh Minh Trieu (Man). I come from Vietnam, this is my first time in Taiwan. I feel everything is wonderful when living and working at National Chung Cheng University, Taiwan. Chung Cheng is a very big university, with lots of trees and fresh air like Vietnam. The food in Taiwan is delicious, some dishes are similar to Vietnam.

The members of the renewable energy laboratory are very friendly and always help me. The Taiwanese are very kind, they help me a lot. I would like to thank the members of the laboratory, especially Mr. Thang, Mr. Tung and Mr. Huy.

Furthermore, I would like to thank Professor Yuan-Kang Wu. He has helped me a lot in the past 3 months. Professor Wu works very hard, even at night and on weekends. I admire him very much. He always guides me enthusiastically even though at first I could not catch up with his working style. He guided me to make a good presentation report so that readers can understand it easily. In addition, he guided me on presentation skills and this was also my first time presenting in English so mistakes were inevitable. Thanks to that, I was able to confidently communicate with foreigners because I was very shy before. After the reports, he asked me questions so I knew which parts of my reports were lacking. Although the 3-month period was very short, I learned a lot from the professor and my friends here.

When I return to Vietnam, I will probably miss this place very much. I love this place very much and hope I have the opportunity to come back here to study in the future.

BUI KHANH HAO

I am Bui Khanh Hao from Vietnam. I have just completed a 3-month internship at CCU, Taiwan. This internship has left me with many memorable memories.

First of all, I would like to thank Professor Wu for supporting me a lot during my internship. At first, I had a lot of difficulties in adapting to the new environment. However, the professor always supported, guided and helped me so that I could complete this internship. I am very grateful for that.

When I entered CCU, the first thing that impressed me was that the campus was very large. The school has a lot of trees and the buildings are big and sturdy. The air in CCU is very fresh and there are many animals. The campus is very beautiful so I have a lot of pictures in my phone

Everyone in my lab is awesome. They have always helped me with my work. I would like to thank Mr.Tung and Mr.Huy who have always supported me when I had difficulties in my research. Especially, I would like to thank the Taiwanese students who provided the necessary equipment in the lab. Everyone made me feel like a family.

After 3 months of internship at CCU, I have improved a lot. My skills are improved day by day after meetings with professors. When I return to Vietnam, I will miss you very much. I sincerely thank everyone.

LAM HONG PHUC

My name is Lâm Hồng Phúc, and I am from Vietnam. This is my first time traveling abroad and also my first time visiting Taiwan, a place that Vietnamese people often refer to as the "Island of Jade." The learning and cultural experiences at CCU and in Taiwan have given me many unforgettable memories.

When I arrived at CCU, I was truly impressed by the architecture of the university. The buildings have unique architectural styles with warm, earthy tones, giving the campus a timeless yet vibrant atmosphere. As someone who loves classical architecture, I had the opportunity to take many beautiful photos of this place.

Professor Yuan-Kang Wu has been a major source of inspiration for me. In every conversation with him, I could always feel his warmth and smile, which made me feel more at ease. He often encouraged me to explore new directions through his questions, insights, and advice. Working with him, I learned to expand my thinking in various ways. Moreover, he was very patient in providing feedback and guidance, helping me improve my skills. I am incredibly grateful for the opportunity to work with him.

My roommates at CCU, especially theVietnamese students, were all very kind and willing to help me. My colleagues in the lab were always supportive whenever I had questions about research or life at CCU. Additionally, I made new friends from both Vietnam and other countries, making me feel like I was living and working at home.

Although I only had three months at CCU, this time will forever remain a memorable part of my life. I dared to try many new activities that I had never done before and gained a lot of knowledge from those experiences. I also enrolled in a beginner's Chinese class and started to fall in love with the language. My skills and knowledge have improved significantly. I enjoyed my life in Taiwan and felt very happy. I eagerly look forward to the day I can return to this wonderful country again.

In closing, I want to express my deepest gratitude to Professor Wu for granting me this opportunity and for his enthusiastic guidance throughout my internship. My heartfelt thanks also go to everyone at CCU who has supported me on this journey. I truly hope to have the chance to return to CCU and collaborate with you all once again.

NGUYEN THUY PHUONG

My name is Nguyen Thuy Phuong. I am from Vietnam, and this is my first time in Taiwan. Living and studying at CCU for six months has been a memorable experience for me.

When I arrived at CCU, I was really impressed because CCU is very spacious and has a lot of trees. I like the feeling of living in a beautiful forest with many kinds of trees and flowers. Since I am a flower lover, I feel excited to discover new flowers every day, and as a result, my phone has a lot of pictures of them.

Professor Yuan-Kang Wu is one of the people who inspires me the most. He is very hard-working and eager to learn. In every discussion we have, he is always cheerful and smiling, which also makes me feel more comfortable. He often gives me some questions so that I can think and research more deeply. Therefore, after working with him, I also learn to expand my thinking to many aspects. Moreover, he is very patient in giving feedback and advice to help me improve my skills. I am very grateful for this opportunity to work with him.

My labmates are all nice, especially the Taiwanese students. They are very enthusiastic and willing to help me. My colleagues in the lab, Mr. Tung and Mr. Thang, have always supported me when I have questions about the research or living at CCU. Moreover, I also have some new friends from Vietnam and other countries. Although I am an introvert, I can feel comfortable with everyone and feel warm, like at home.

After six months at CCU, I have grown significantly. I've uncovered new aspects of myself, experimented with various activities, and gained a wealth of knowledge from my experiences. My skills and knowledge have greatly improved. I enjoy life in Taiwan and feel happy.

Finally, I would like to sincerely thank Professor Wu for giving me this opportunity and his enthusiastic guidance throughout my internship. Thank you to everyone at CCU who has helped me in this journey. I hope that I will have another chance to come back to CCU and work with everyone again. I will miss CCU and everyone very much.