香港理工大學智能微電網實驗室
Smart Microgrid Laboratory at The Hong Kong Polytechnic University

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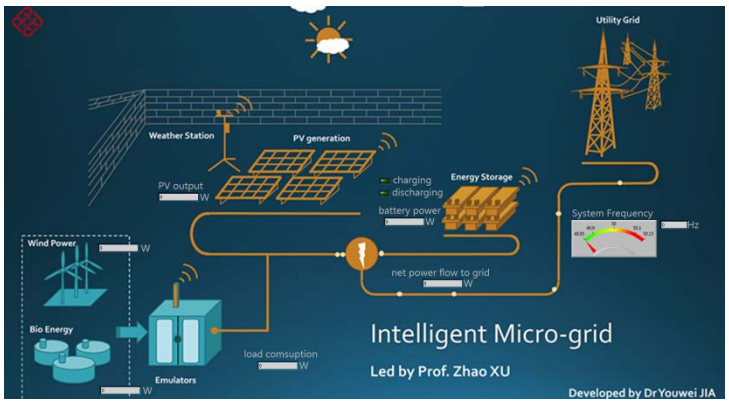
全港首個微網控制實驗室及 CHASE 理想調度追蹤算法的實際應用
First-of-its-kind Laboratory Microgrid Platform and CHASE Algorithm Implementation

研究團隊致力於研究電力的高效應用。團隊構建的智能微電網實驗室集光伏、儲能及電能優化調配為一體，是全港首個微網控制實驗平台，總容量達 4 kw（外觀見圖一，網絡架構見圖二）。團隊以 LabVIEW 軟件開發了智能實時監控系統。同時，作為驗證多種調度及控制策略的在線實驗平台，目前控制週期已短至5秒；其中，中大陳名華教授團隊開發的CHASE在線調度演算法已在此平台得到了成功驗證。

The research crew has been aspiring excellence in the study of efficient utilization of electricity. Their microgrid experimental laboratory platform - a holistic integration comprising photovoltaics, energy storage and optimization dispatch components - is the first-of-its-kind in Hong Kong, with total capacity of 4 kw (See Fig. 1 for the laboratory outlook and Fig. 2 for the network architecture). The team established the smart real-time monitoring system using the software LabVIEW.

圖一. 智能微電網實驗室的外觀。
Fig. 1. Outlook of the laboratory microgrid platform.

At the same time, it acts as the implementation verifying platform for various online experimental dispatch and control strategies, with control cycle as rapid as 5 seconds. Here, the CHASE online energy generation scheduling algorithm developed by Prof. Minghua Chen from CUHK was successfully verified.



圖二. 團隊構建的智能微電網實驗室運行網路架構之圖示。
Fig. 2. Network architecture of the laboratory microgrid platform established by the team.

粒化計算為本的概率預測技術
Granular Probabilistic Interval Forecasting

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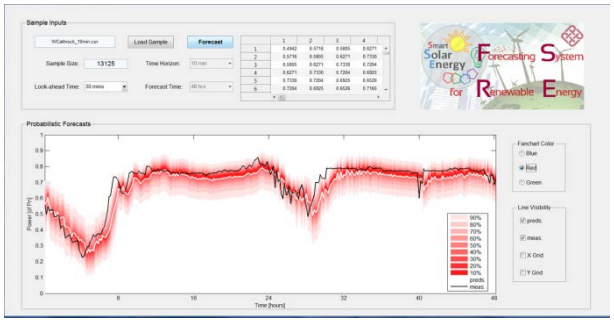
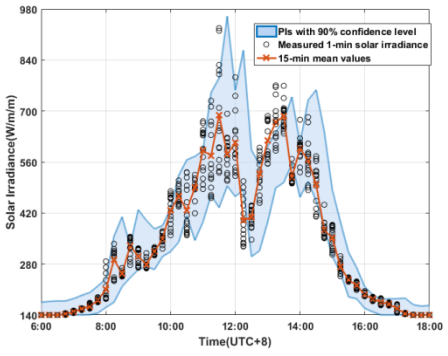
為達到更佳的能源效益，微電網中可再生能源的發電和負荷的準確預測不可或缺。一套準確的預測策略能為微電網提供供需模式的重要資訊，幫助決策者制定適合的控制和調度策略。其中，粒化計算為本的概率預測技術被公認為一種相當有展望的方法。事實上，任何預測都存在不同程度的誤差，概率預測能夠將這種不確定的誤差信息以不同概率等級的預測區間形式體現出來，決策者可以此制定相應的控制策略，保證經濟和可靠運行。團隊與香港天文台合作，開發了性能優秀的粒化概率預測技術。研究結果顯示，在以15分鐘為間隔的光照輻射預測结果中，所產生的可信度為90%的預測區間幾乎可以覆蓋90%的觀測值，證明該方法非常可靠（圖四）。該技術已成功在香港天文台京士柏光照強度數據的短期概率預測上應用，將來更有望應用於太陽能及其他可再生能源的微電網上。

Forecasting the generation and consumption of electricity is essential to achieve energy efficiency. An accurate forecasting strategy can provide important information for supply and demand pattern to the microgrid, assisting policy makers to devise suitable control and dispatch strategy. Here, granular probabilistic forecasting technology has been shown to be a promising approach. Actually, all forecasting approaches involve errors. Probability forecasting is able to reflect different levels of errors by prediction intervals, thereby allowing policy makers to deploy a suitable control strategy to guarantee economic and reliable operation. In collaboration with the Hong Kong Observatory, the team developed high-performing granular probabilistic forecasting technology. (In Fig. 4, the high reliability of the approach was verified by the 90% confidence level of the 15-minute interval prediction results of solar irradiance, which means 90% overlapping of observed values) This technology has been successfully implemented in the short-term probabilistic forecasting of the solar irradiance data of King's Park at the Hong Kong Observatory, and is applicable to solar and other renewable energies in future.



圖三. 團隊以 Matlab 軟件設計的**再生能源預測系統 (FSRE)**，以粒化計算為本的概率預測技術來預測太陽光照。

Fig. 3.. Using the Matlab software, the team developed the **Forecasting System for Renewable Energy(FSRE)** for forecasting solar irradiance using granule-based interval technology.



圖四. 以 15 分鐘為間隔的光照輻射預測结果中，所產生的可信度為 90% 的預測區間幾乎可覆蓋 90% 的觀測值，證明該方法非常可靠。

Fig. 4. The 15-minute prediction intervals of solar irradiance via the granule-based model have a nominal confidence level as high as 90%.

全港首個智慧型電氣負載控制器
First-of-its-kind Smart Demand Controller in Hong Kong

維持頻率穩定是保障電力系統安全運行的關鍵因素。傳統上，電網的頻率調節只能由發電方承擔，花費非常昂貴。許教授的團隊成功研發本港首個能實時回應頻率變化的智慧型電氣負載控制器，可用在不同家居電器而且體積細小（約一般信用卡大小），很適合香港家居使用（圖五）。此控制器讓電器即時參與頻率回應，在頻率過低時，切斷非重要負荷；在系統頻率恢復時，迅速恢復供電。此控制器能從用戶方分擔頻率平衡的負荷，對整個電網系統的穩定非常有利。冰箱、空調和熱水器等大型家居電器由於回應快速及可控性高，非常適合使用此控制器。此外，相對於傳統方法，團隊提出的這種策略不僅能提高回應速度，更不會對環境造成任何危害並且可以大幅降低調節成本。此控制器的推廣將對香港電網的穩定運行有重要意義。

Frequency stabilization is the key factor to ensure power system operation safety. Conventionally, frequency regulation is generally provided by the generation side at high cost. The team successfully developed a real-time smart demand controller, the first of its kind in Hong Kong, which can be applied in different home appliances, in sizes as small as a regular credit card, which is very suitable for home use in Hong Kong (Fig. 5). Thanks to the devised controller, the home appliances are able to contribute to frequency stabilization in real time. That is, non-critical appliances are switched off when frequency significantly drops, and rapidly resume power supply once the frequency is restored. This controller can share the load of frequency stabilization from the user side, bringing great benefits to the entire microgrid system. Its fast response and high controllability make this controller very suitable for application to large home appliances like refrigerators, air-conditioners and water heaters. In contrast to the conventional way, the approach suggested by the team not only improves the response rate, but is also environmentally friendly and substantially reduces costs. Widespread application of this controller holds significant potential for supporting system frequency stability in Hong Kong.

圖五. 智慧型電氣負載控制器體積細小，非常適合香港家居使用。

Fig. 5. The smart demand controller is as small as a regular credit card, which is very suitable for home use in Hong Kong.

圖六. 許昭教授的研究團隊。

Fig 6. Research team of Prof. Zhao Xu.

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