A Zero-Carbon Asia-Pacific Super Grid

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In this study, we modelled a zero-carbon Super Grid in the Asia-Pacific which is powered by solar photovoltaics, wind turbines, hydropower, and other renewables with the support of pumped-storage hydro and high-voltage direct-current transmission. The interconnection of electricity grids over millions of square kilometres allows sharing of geographically distributed renewable energy resources across the Asia-Pacific region.

The Asia-Pacific Super Grid

The hypothetical Asia-Pacific Super Grid is a large-scale interconnected electricity system in Southeast Asia, which entails a high-voltage direct-current transmission backbone (overhead, underground or submarine) on top of existing transmission and distribution network. The Super Grid spans 4 time zones from GMT+6.5 in Myanmar to GMT+9.0 in Papua and nearly 50 degrees of latitude from the Northern Hemisphere to the Southern Hemisphere. The major load centres in the Southeast Asian countries, Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste and Vietnam, are interconnected via the Super Grid. In addition, there are potential extensions to Western Australia and the Northern Territory of Australia in the south, and to Southwest China and Northeast India in the north. Due to the archipelagos in Indonesia and the Philippines, there are multiple transmission nodes located in the major islands of these two countries. Renewable energy resources are connected to the adjacent Super Grid nodes through high-voltage alternating-current or direct-current transmission lines depending on the distance, transmission capacity and routes.

Renewable energy resources in Southeast Asia

Solar energy resources are excellent in Southeast Asia. The capacity factors of solar photovoltaics are: 12% in Hanoi; 14% in Manila, Kuala Lumpur and Singapore; 15% in Yangon, Bangkok, Ho Chi Minh City and Jakarta; 16% in Vientiane and Brunei; 17% in Phnom Penh and 18% in Timor-Leste. The average capacity factor of solar photovoltaics across the region is about 15% (based on the Solcast historical weather data). In northern Australia, the capacity factor of solar photovoltaics can reach 21% for fixed and 26% for single-axis tracking. This is the competitive advantage of the Australia's solar energy which can be potentially exported to Indonesia and Singapore via the Super Grid.

In comparison, the excellent wind energy resources are widely distributed in Myanmar, the Philippines, Thailand and Vietnam, but they only exist in a few regions in Cambodia, Malaysia and Indonesia. A mean wind speed of 8 m/s at a hub height of 150 m translates to an average capacity factor of about 40% across the windy zones in Myanmar, the Philippines, Thailand and Vietnam.

The majority of the hydropower resources are located in the Greater Mekong Subregion and its upstream. Southwest China has a hydropower potential of 500 gigawatts while Northeast India constitutes about 40% of the total hydropower potential in India. Therefore, extending the Super Grid to Southwest China and Northeast India allows Southeast Asia to access reliable and flexible hydropower resources. In addition, pumped-storage hydro resources are widely distributed in almost every country in Southeast Asia, except for Singapore and Brunei due to the geographic constraints. In the two countries, battery storage would be useful for energy day-night shifting. However, battery storage (about $400/kWh) is still more expensive than pumped-storage hydro (about $75-150/kWh) when utilised for large-scale energy time-shifting, and it has a much shorter lifespan (10 years) compared with hydropower projects (50-100 years).

Modelling results

The modelling results show that this Super Grid costs about 90 U.S. dollars per megawatt-hour ($/MWh), including the costs of electricity generation, storage and transmission technologies. Solar photovoltaics are the largest cost component in the levelised cost of electricity (LCOE), followed by energy storage, transmission, wind turbines and other renewables. Energy reliability can be effectively met through energy time-shifting (pumped-storage hydro) and energy geo-shifting (high-voltage direct-current transmission) across the region.

It is noted that this LCOE figure may further reduce by $15-25/MWh as the price of solar photovoltaics is likely to be halved in the next decades according to the IRENA report. Additionally, integration of electric vehicles in future energy systems would help reduce the LCOE because the charging of electric cars will contribute to significant storage capacity as well as very large demand flexibility. Consequently, the levelised cost of the hypothetical Asia-Pacific Super Grid would be highly competitive compared with the unsubsidised costs of fossil fuels-based energy systems in Southeast Asia. New coal-fired and natural gas-fired power plants in Southeast Asia cost about $60-90/MWh and $90-110/MWh, respectively. In addition, the fossil fuels-based energy systems will fail to meet the emission target and heavily rely on imports (to accommodate the rapidly growing demand for electricity) which raises energy security concerns. In contrast, the zero-carbon Asia-pacific Super Grid represents a promising renewable and affordable energy future in Southeast Asia.

References

IRENA, 2019, ‘Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation: paper)’, International Renewable Energy Agency, Abu Dhabi.