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REVIEW ARTICLE

Review on hydropower in Myanmar

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Abstract
Hydropower is the world's leading renewable energy resources in electricity generation that produces 71% of electricity more than other forms of energy sources such as coal, gas, and oil which are not reliable and gradually diminish day by day. Therefore, hydropower is essential and considered as an economical factor for producing electricity. There are many untapped hydropower resources in the world. The developing country, Myanmar, is also have about 100 GW unexploited energy potential from the rivers for hydropower electrification. This paper is the review paper which presents about the condition of the hydroelectricity in Myanmar in detail.

Keywords Hydropower · Electricity · Myanmar

Introduction

Hydropower is a clean energy that is a prosperous gift from nature to produce electricity. It is the power derived from continuous running water and falling water. Although it has some drawbacks to use, it cannot be denied for its advantages like abundant, reliable, low operating costs and can supply as a backup power during blackout situation and can also use as surplus energy in base load and peak load conditions in pumped storage power station. Currently, it is generated in over 150 countries and China, Brazil, Canada, India, the USA, and Russia are the most hydropower reliable countries. The world's largest hydropower station, "Three Gorges" hydropower station with 22,500 MW installed capacity, is located in China. Myanmar, a Southeast Asian country, is bordered by Thailand and Laos to the east, India and Laos to the west, China to the north, Bangladesh to the northwest, and about 1930 km coastline along Bay of Bengal and Andaman Sea to the south. It is 676,600 square kilometers in size, and the population is about 54.36 million (Tun 2019). The country is hot and humid, and there are three main seasons—summer, rainy season and winter. Rainfall is up to 5080 in coastal areas and average 1500 mm in central areas. There are mainly four rivers crossing Myanmar—Ayeyarwady, Thanlwin, Chindwin and Sittaung rivers. Myanmar is a struggling country to develop with lower–middle income of $1455 per capital in 2017. The GDP rate increases to 6.7% in 2017–2018, and it is predicted that it is going to be increased 7% in 2019–2020. It has many opportunities to develop because of having such a plenty of 62% of workable population, naturally provided resources, renewable energy such as hydropower, incoming foreign investments, and strategically located geographical region between two powerful countries: China and India. On the other side, it needs to reform in many sectors like national reconciliation, job opportunity, electrification, education, and heath. Peace and stability are the first priority consideration factor for the country development, and the government needs to implement national reconciliation during the transition state to democracy (Kattelus et al. 2015). And the government has to reduce the unemployment level by creating job opportunities for the citizens. The literacy rate of Myanmar is 92.6% for males and 86.9% for females according to Myanmar Census in 2014. Six out of 10 students who live in rural areas are likely to drop out during their primary education. Only one third of the people can get electricity, and 70% of the people who live in rural areas still live in darkness (Nam et al. 2015). During the transition period to democracy, foreign investment is also one of the factors to develop country's economic. The main factor that burdens foreign investment is not enough electricity to supply industries. Therefore, energy is vital for nation's social and

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economic development. Currently, Ministry of Electricity and Energy has signed 49 contracts MOA, MOU, JVA with foreign companies concerning with hydropower to fulfill the national energy needs. Supervisory Control and Data Acquisition (SCADA) system is started implementing in Yangon Electricity Supply Corporation to supervise the power grid. The electricity supply in Myanmar is 1275 MW in Yangon, 430 MW in Mandalay, and 1495 MW in other states and divisions, and the totaling capacity is 3200 MW. According to census counting in nation, there can be supplied only 4.29 million households totaling from 10.878 million households. The electricity consumption was 2527 MW in 2015, 4530 MW in 2020, 8121 MW in 2025, and 14,542 MW in 2030 for each described in the National Electricity Master Plan (Aye 2017). The electric tariff is 35 kyats/kWh for household consumption and 150 kyats/kWh for industrial consumption (Shah 2014). The first small-scale hydropower plant was established at Yeni River in 1898, and the total installed capacity was 460 kW. The first hydropower plant connecting to national grid was Baluchaung (2) hydropower station operated with six numbers of turbines (each in 28 MW). This paper emphasizes on types of hydropower plants detailed with reservoir-type, runoff river-type, pumped storage-type, tidal power-type, and small-scale hydropower in Myanmar. Further, it highlights about the constructing hydropower situation in Myanmar divided into three sections—present hydropower stations in Myanmar, coming up power plants in Myanmar, under implementation hydropower projects in Myanmar, and factors affecting in construction of hydropower plants.

Types of hydropower plants

Types of hydropower plants depend on topography, head, installed capacity, conveyance system, exploitation, storage, and energy conversion mode. They are reservoir type, runoff river type, pumped storage type, and tidal power type.

Reservoir type

The reservoir type hydropower plant is constructed the dam at gorges, valleys and it is impounded the river water for the purpose of irrigation, electricity generation, flood protection, supplying drinking water, navigation and recreation. Water discharged from the dam forces the turbine to rotate, and the turbine driving force makes the generator to produce electricity. The water is stored sufficiently inside the reservoir during rainy season to operate enough in dry season. The stored water in the reservoirs regulates fluctuations in the electricity transmission network, and therefore, it is suitable for both peak and base loads. The reservoir can also protect flood due to natural disaster. Most of the hydropower plants used in Myanmar are reservoir type, and most of them are mainly used for electricity production and irrigation.

Runoff river type

In this type, the water flows from the river to the power plant via the canal or penstock and makes the electricity generating turbine to rotate. It is eco-friendly type and without polluting energy source. Runoff river plant can be classified as two categories: with poundage and without poundage. Having poundage in plant can be used water for daily load requirements. Runoff river plant which does not have poundage for water storage relies on weather and seasonal river water flow rate. In Myanmar, Baluchaung (1, 2, 3) hydropower plants are cascade-type hydropower stations generating 24% of electricity for country's demand.

Pumped storage type

Pumped storage hydropower system is designed for balancing load in controlling the network frequency and reserves (李继清 2011). Moreover, it can store surplus energy during off-peak hours and can generate it again in peak hours. It also protects power cut from intermittent power sources and helps nuclear power stations to level with system frequency. Although it has to be considered appropriate geography and the higher capital costs, it can span life more than 100 years with low operating costs. It has two reservoirs: the upper reservoir and the lower reservoir. In some places, man-made reservoirs are used and abandoned mines or natural reservoirs are used in some other places. The upper reservoir is used during peak load, and the tailrace water flows down to lower reservoir. The water from the lower reservoir is pumped back again to the upper reservoir during off-peak hours (Táczi 2016). Reversible turbine is used as pump and turbine. There are two main types of pumped storage station: Closed-loop system is used water to pump back to the upper reservoir from lower reservoir, and open-loop system is used for both pumping water and producing electricity from natural flowing water. Presently, variable speed pumped storage design, seawater, underground, compressed air, and undersea pumped storage designs are used in the world. In Myanmar, pumped storage hydropower plants are not available presently, but there are many potential topographic places to establish pumped storage hydropower plant. Among them, the author chooses one dam to construct hydropower plant named Dagwin or lower Thanlwin

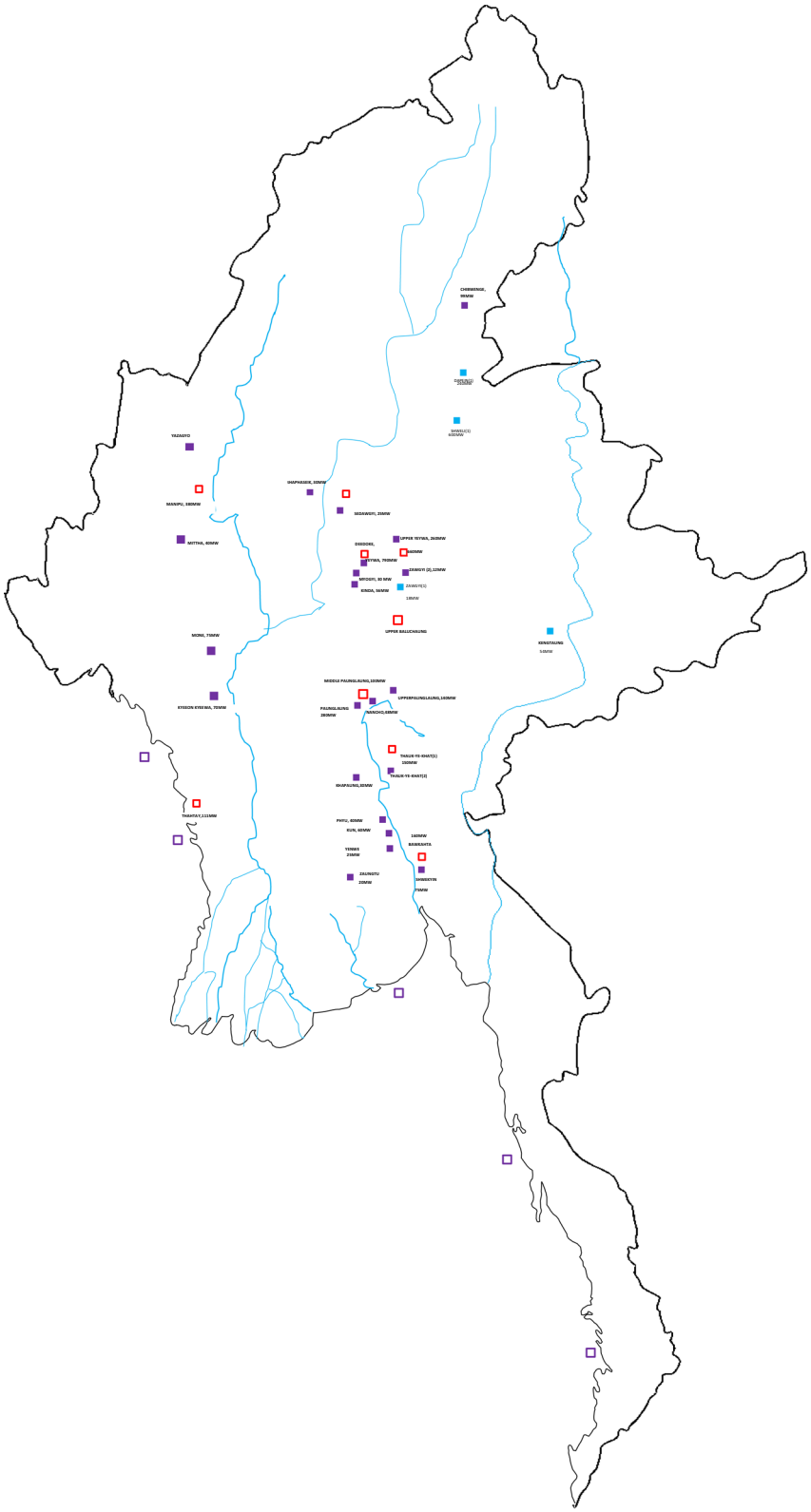

Fig. 1 Myanmar national grid system (existing and under construction)

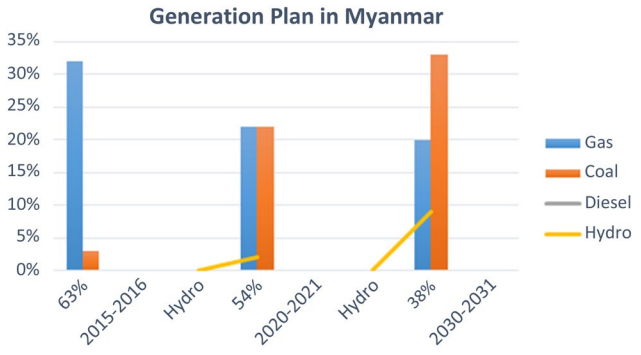

Fig. 2 Generation plan in Myanmar

dam as shown in Fig. 1, and the government is also planning to establish it in the future.

Tidal power type

The movement of water called tides appears due to the gravitational attraction between moon and sun when the earth rotates. Tidal energy is a water potential energy that uses the high and low tides to convert another form of energy for some other purposes like producing electricity. The tides get into the reservoir with barrages and come back through the water gate that has installed tidal turbines. The turbines turn the generator with the water acceleration to generate hydroelectricity. In some places like UK, China, and Korea, the tidal turbines without needing dam are used under the waterbed along the coastline and it costs cheaper and low environmental impact than tidal power barrages. The world largest tidal power station is located in South Korea, and generating capacity is 254 MW. Myanmar possesses the longest coastline which is 1930 km long connecting to Bay of Bengal. About 40% of the people live along the coastline, and most of them still could not use electricity. Therefore, if tidal power plants are established on the shoreline, people on that area are no need to worry about electricity and also can support to the national grid. The author suggests about five places to construct tidal power plants as shown in Fig. 2.

Sizes of hydropower plants

Small-scale hydropower

Because of environmental concerns and large capital cost, a large hydropower station is less attraction and small-scale hydropower is one of the solutions for those who live in isolated regions due to easily maintenance, operation, and cost-effective. Small-scale hydropower stations have been exploited 78GW almost about 36% in the world, and 64% are potential still need to be utilized (Lei 2016). For more than 10 years in Myanmar, small hydropower producers in rural areas have been searching supportive policies for self-electrification, and later, they installed their own biogasification plants and micro-hydropower stations. Most of the small-scale hydropower plants are runoff river types and are limited from 2.5 to 25 MW, but the maximum is 50 MW in China and 10 MW in Europe, and a micro-hydropower also has the limitation of up to 100 kW (Kaunda et al. 2012). There are 210 numbers of less than 10 MW small potential hydropower projects need to exploit in Myanmar and 32 numbers of small hydropower stations with the installed capacity of 33327 kW have been implemented at present. It means 45% of small, 20% of mini-, 15% of large, and 5% of micro-hydropower potential are need to be exploited (Dim et al. 2017). The largest station of small-scale hydropower is located in NantKhamKha (Kachin State) with the installed capacity of 4750 kW. The smallest station is located in Palettwa (Chin State), and the installed capacity is 50 kW.

Large-scale hydropower

Large-scale hydropower plants, more than 100 MW, are reliable, cost-effective and can produce up to 100 years. China, Brazil, Venezuela are leading large-scale hydropower producer countries even though they can affect environment and society by damaging ecosystem, methane gas emissions, evaporation, siltation, and migration of people due to dam construction. They can even give risks due to dam failures. On the other hand, they can generate electricity in large scale to meet the national demand. In Myanmar, Myitsone hydropower project is the largest one in the country which can produce 6000 MW to China and Myanmar and the project has been suspended because of protesting by local people.

Constructing hydropower plant situation in Myanmar

Present hydropower station in Myanmar

Currently, a total of 27 numbers of hydropower plants with the total installed capacity of 3221 MW have been networked with the national grid. Among them, two numbers of hydropower stations with 172 MW total installed capacity have been constructed by local companies on build–operate–transfer (BOT) basis and three numbers of hydropower stations with 939 MW total installed capacity have been established by foreign companies on joint venture basis (Aye 2017). The rest 22 numbers of hydropower stations have been constructed by Ministry of Electricity and Energy. The distribution steps from each hydropower station are explained below. Firstly, the generation output from Baluchaung no (1) and Baluchaung no (3) hydropower

Table 1 Current hydropower stations in Myanmar

Nos.	Name of stations	Number of machine	Type of machine	Installed capacity	Name of river	Type of hydropower plant
1	Zawgyi no (1)	3	Francis	18	Zawgyi	Runoff river
2	Keng Tawng	3	Francis	54	Nantein	Runoff river
3	Kinda	2	Francis	56	Panlaung	Rock fill
4	Sedawgyi	2	Kaplan	25	Chaungmagyi	Rock fill
5	Zawgyi no (2)	2	Francis	12	Zawgyi	Arch
6	Thaphanseik	3	Kaplan	30	Mue	Earth fill
7	Mone Chaung	3	Francis	75	Mone	Rock fill
8	Kyeeohn Kyeewa	2	Kaplan	74	Mone	Earth fill
9	Baluchaung no (1)	2	Francis	28	Baluchaung	Runoff river + dam
10	Baluchaung no (2)	6	Pelton	168	Baluchaung	Runoff river + dam
11	Zaungtu	2	Kaplan	20	Bago	Earth fill
12	Paung Laung	4	Francis	280	Paung Laung	Rock fill
13	Yenwe	2	Francis	25	Yenwe	Earth fill
14	Kabaung	2	Francis	30	Kabaung	Earth fill
15	Yeywa	4	Francis	790	Myitnge	Roller compacted concrete
16	Shwe Gyin	4	Francis	75	Shwegyin	Rock fill
17	Kun Chaung	3	Francis	60	Kun	Rock fill
18	Shweli no (1)	6	Francis	600	Shweli	Runoff river
19	Dapein no (1)	4	Francis	240	Dapein	Runoff river
20	Thaukyekhat no (2)	3	Francis	120	Thaukyekhat	Concrete faced rock fill
21	Nancho	2	Francis	40	Nan Cho	Runoff river
22	Phyu Chaung	2	Francis	40	Phyu Chaung	Rock fill
23	Upper Paung Laung	2	Francis	140	Paung Laung	Roller Compacted Concrete
24	Myo Gyi	2	Francis	30	Zaw Gyi	Earth fill
25	Myittha	2	Kaplan	40	Myitta	Earth fill
26	Baluchaung (3)	2	Francis	52	Baluchaung	Runoff River + Dam
27	Chipwe Nge	3	Pelton	99	Chipwe	Runoff river

stations is transported to Baluchaung no (2) hydropower station. The total generation output from Baluchaung nos (1, 2, and 3) is transmitted to Taungoo substation by 230 kv southern transmission line and also transmitted to Tigyit power plant by 132 kv northern transmission line. And then, the total generated power from Tigyit and Baluchaung is combined together and transported to Kalaw substation. The generation output from Kaingtaung and Zawgyi nos (1 and 2) hydropower plants is combined together with the above generation output at Kalaw station and connected with nation grid. The generation output from Shweli and Yeywa hydropower plants is transmitted to Baelin substation and then to Tapyaewa and Thasi substations and finally to Pyinmana substation. The generated power from Upper Paung Laung, Nan Cho, and Paung Laung hydropower plants is combined together at Pyinmana substation. The generation output from Thaukyegat, Koonchaung, Phyuchaung, Kapaung hydropower plants is integrated together and sent out to Pyinmana substation from Taungoo substation. All the generated powers are united at Pyinmana substation and transmitted to Taungtwingyi substation. The generation output from Shwekyin, Yenwe, Zaungtu hydropower stations is transmitted to Yakhine state via Oakchitpin substation. The generation output from Kinda hydropower station is sent out to Thasi substation. The generation output from Myogyi hydropower station is connected to national grid via Baelin substation. The generated power from Sedawgyi, Thaphanseik, Chipwenge hydropower stations is combined together at Kyaukpahtoe substation. The generation output from Dapein hydropower station is distributed to Bamaw, Mansi and Moemauk cities, and the rest power are exported to China (Table 1).

Coming up power plants in Myanmar

The national grid transmits the electricity demands to the whole country via 66kV, 132 kV, 220kV transmission networks which is supplied high voltage electric from hydro, gas, coal and diesel power plants. There are totally 27 numbers of hydropower plants, 20 numbers of gas turbine power

plants, 7 numbers of steamed turbine power plants, and one number of coal power plant in Myanmar. According to Fig. 2, National Electricity Master Plan in 2015 and 2016 of the hydropower plants comprised of 63% with 3158 MW, gas power plants comprised of 32% with 1623 MW, coal power plants comprised of 3% with 120 MW, and diesel power plants comprised of 2% with 101 MW (Oo 2017). In 2020 and 2021, hydropower plants, gas power plants, coal power plants, and renewable energy will be increased to 4721 MW, 1969 MW, 1925 MW, and 200 MW. In 2030 and 2031, it will be predicted to produce 8896 MW, 7940 MW, 4758 MW, and 2000 MW in hydro, coal, gas power plants, and renewable energy. The target is 50% of population to be electrified in 2020, 75% of population to be electrified in 2025, and 100% of population to be electrified in 2030. The following pie charts show the generation of power plants from 2015 to 2031. Coming up solar projects are 150 MW at Nabuaing (Myingyan), 150 MW at Wundwin (Meikgtila), 880 MW at Sagaing, Mandalay, 170 MW at Min Bu, 100 MW at Thapyaysan, and 10 MW at Shwemyo, and total capacity is 1460 MW. Future plan floating solar projects are at Kun Chaung dam (30 MW), Zaung Tu dam (30 MW), and Shwe Gyin dam (30 MW). Coming up wind power projects are 3648 MW at Chin, Rakhine, Ayeyarwaddy, and Yangon, 830 MW at Rakhine, Ayeyarwaddy, and Yangon, 1000 MW at Shan, Kayah, 1000 MW at Tanintharyi, Mon, Kayin, and 30 MW at Chaung Thar, and total installed capacity is 6538 MW. About 34 hydropower projects in Ayeyarwaddy River, eight hydropower projects in Chindwin River, 11 hydropower projects in Sittaung River, 21 hydropower projects in Thanlwin River, 4 hydropower projects in Mekong River, and 14 hydropower projects in other rivers are future plan to be exploited.

Under implementation hydropower projects in Myanmar

At present, eight numbers of hydropower projects are underway in construction and they are 30.4 MW at upper Baluchaung in southern Shan state, 51 MW at Upper Kengtawn in southern Shan state, 280 MW at Upper Yeywa in northern Shan state, 1050 MW at Shweli-3 in northern Shan state, 111 MW at Thahtay in Rakhine state, 3.2 MW at Upper Nattrum in Kachin state, 66 MW at Deedoke in Mandalay region, and 100 MW at Middle Paunglaung in Naypyitaw. All the hydropower projects are constructed by Ministry of Electricity and Energy except upper Baluchaung implemented by local companies in build–operate—transfer (BOT) basics.

Factors affecting in constructing of hydropower plant in Myanmar

The main factors that can delay the construction of hydropower plants in Myanmar are

1. Difficulties to implement hydropower plants in some unpeaceful regions.
2. Hard to get agreement from local people to tackle in environmental concerns and affecting local people lives (Dapice 2015).
3. Problem facing in dealing with land ownership, archeological sites, and natural areas.
4. Obstacles from "No Dam" protestors.
5. Consideration on enough budget to construct large hydropower plants.

Conclusion

1. It is suitable that the developing country, Myanmar, should emphasize on using hydropower more than oil and gas because of long term cost-effective, clean, and abundant in region. In the future, if the country can produce more electricity from hydropower, it will get more profits from selling electricity to neighboring countries like Laos which is the battery of Asia. Presently, Myanmar has only runoff river and reservoir-type hydropower plants, and therefore, it is suggested that pumped storage hydropower plant can be used to regulate load demand fluctuations and can save electricity during off-peak hours.

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Compliance with Ethical Standards

I certify that this manuscript is original and has not been published and will not be submitted elsewhere for publication while being considered by Applied Water Science. And the study is not split up into several parts to increase the quantity of submissions and submitted to various journals or to one journal over time. No data have been fabricated or manipulated (including images) to support your conclusions. No data, text, or theories by others are presented as if they were our own.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent The submission has been received explicitly from all co-authors. And authors whose names appear on the submission have contributed sufficiently to the scientific work and therefore share collective responsibility and accountability for the results. Informed consent was obtained from all individual participants included in the study.

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