TRANSMISSION MASTER PLAN FOR RWANDA

April 2018

HIGH VOLTAGE TRANSMISSION NETWORK

PURPOSE OF TRANSMISSION PLAN

- The function of the Transmission Network (110kV and 220kV) is to evacuate power from the Generation stations to the main substations in the country. The objective is to do this efficiently to minimize losses, enable reliability and flexibility
- To plan and design Internationally Interconnected Transmission lines
- To plan and design the network to function under contingency conditions
- To plan and design how every significant power plant must have more than one evacuation line in order to optimize the availability of the power plants at all conditions.
- To plan and design how existing lines can be upgraded without network interference.

CHALLENGES WITH THE EXISTING TRANSMISSION NETWORK

- Isolated from the Transmission Networks of the neighbouring countries.
- Some substations have only one source of supply and some of them don`t have n-1 connections.
- All power plants have only one evacuation line each which reduces the availability of the power plants during the failure of the evacuation line and this may result to the catastrophic circumstance of blackout.
- Voltage Drop from Ntaruka switchyard towards Rwinkwavu Substation are very high due to the small size of the conductor and long distance.

CONTENTS

- Methodology
- Planning Criteria
- Load Forecast Methodology
- Assumptions
- Network Development
- Load forecast per substation and total
- Load Flow results and analysis
- Recommendations

Methodology

1. Model the existing network using PowerFactory
2. Model network with existing loads
3. Do load forecast
    1. Existing network
    2. New Electrification
    3. Bulk loads
4. Simulate existing network with future loads to determine network supply limits
5. Model future networks
6. Simulate future loads on future network
7. Determine problem areas and test alternative proposals

PLANNING CRITERIA

Planning Criteria

- All transmission lines in Rwanda must have n-1 supply option (supplied from at least two sources).
- All Power Substations in Rwanda must have n-1 supply (at least two evacuation options).
- Evacuation of Generation must be able at n-1 conditions (at least two evacuation options).
- All new transmission lines are constructed to allow for two circuits (allow for future growth – use same corridor and structures).
- The transmission network will be operated at 110kV where possible until the load justifies the 220kV (reduce reactive losses).
- The 220kV lines used for major international load transfer will be operated on 220kV.
- Distribution (15kV and 30kV) must not be on the same transformer as the 220kV network. Distribution must be done from the 110kV intermediate voltage network (Reliability of the 220kV network may not be compromised).
- Transmission Substations must be designed and positioned in accordance with the requirements of the Distribution Master Plan.
- All substations shall have a double HV busbar with split or double MV busbar and coupler breaker to allow operational flexibility (and availability) of the network.
- All new substations must be designed and prepared for two transformers, even if only one is installed initially.
- A minimum transformer size of 20MVA must be used for all new substations.
- International Consultants shall follow the REG master plan guidelines for Transmission network development.

LOAD FORECAST METHODOLOGY

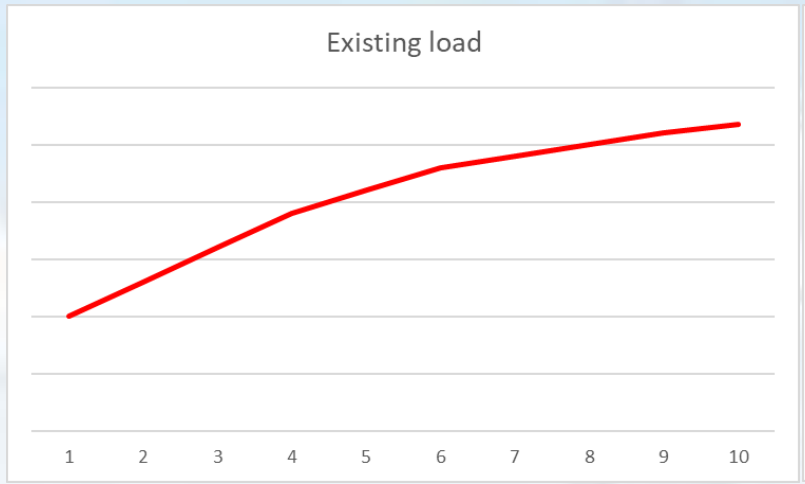
LOAD FORECAST METHODOLOGY

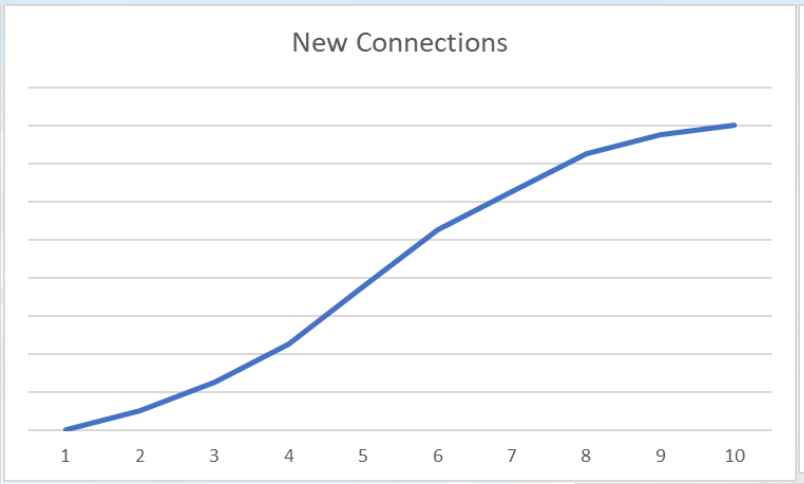
Load Growth Calculations

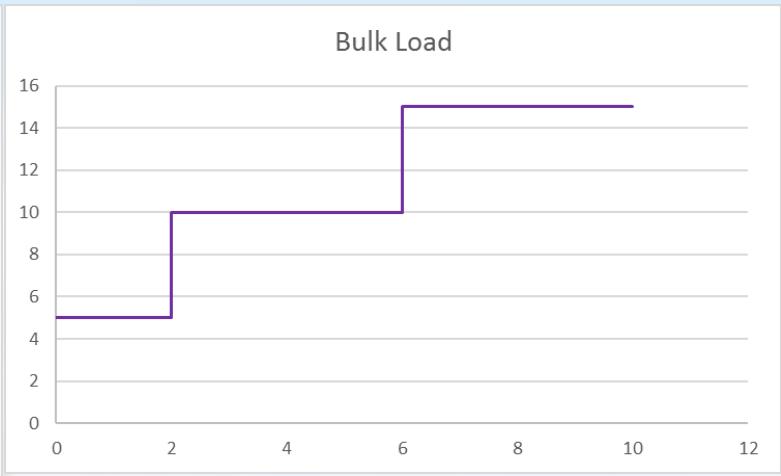
- **Load growth is a combination from different growth types.**

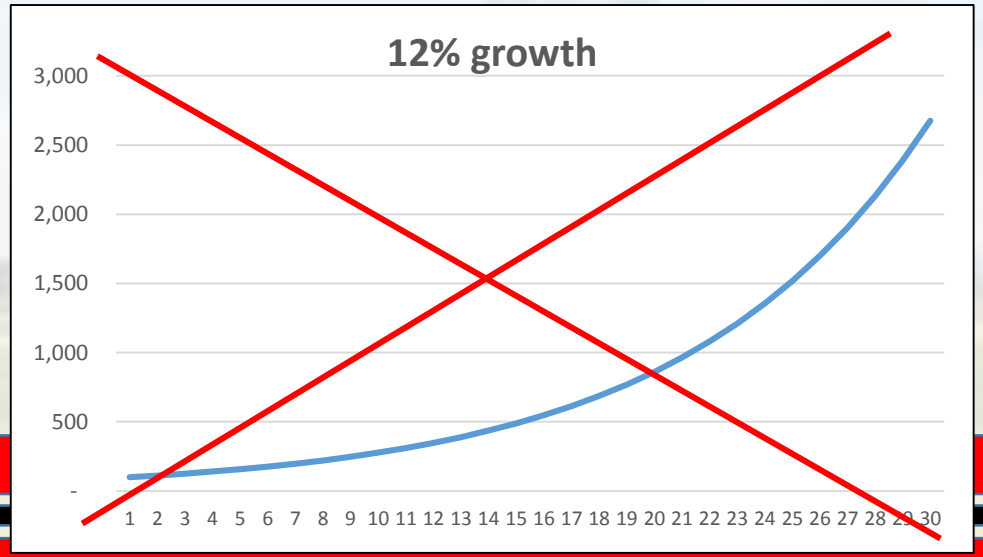
LOAD GROWTH CALCULATIONS

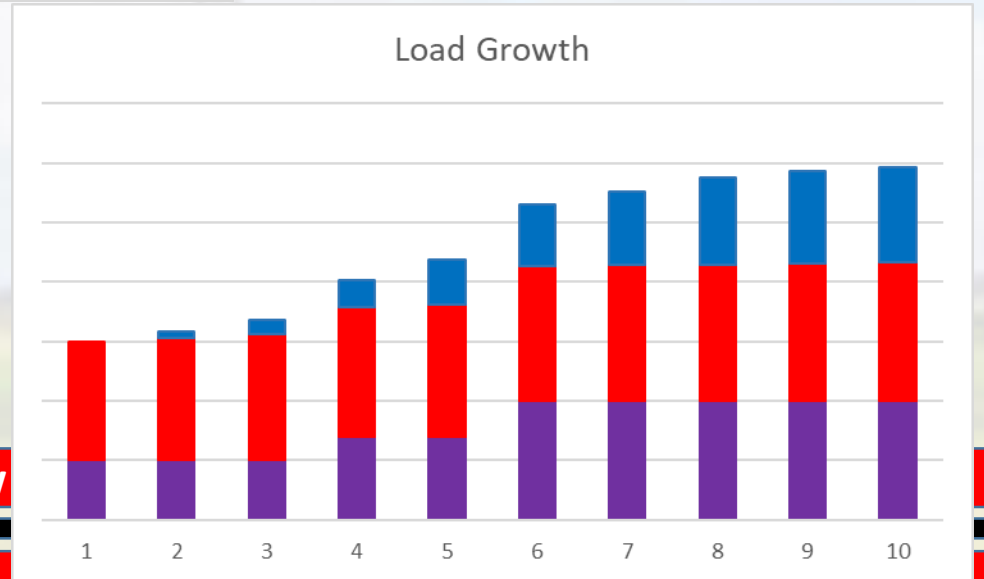
1	Growth on existing networks (grow to saturation)	(a)Growth of existing consumers
		(b)Fill-in connections
2	New Networks connections (S-Curve)	
3	Bulk loads (Step input)	









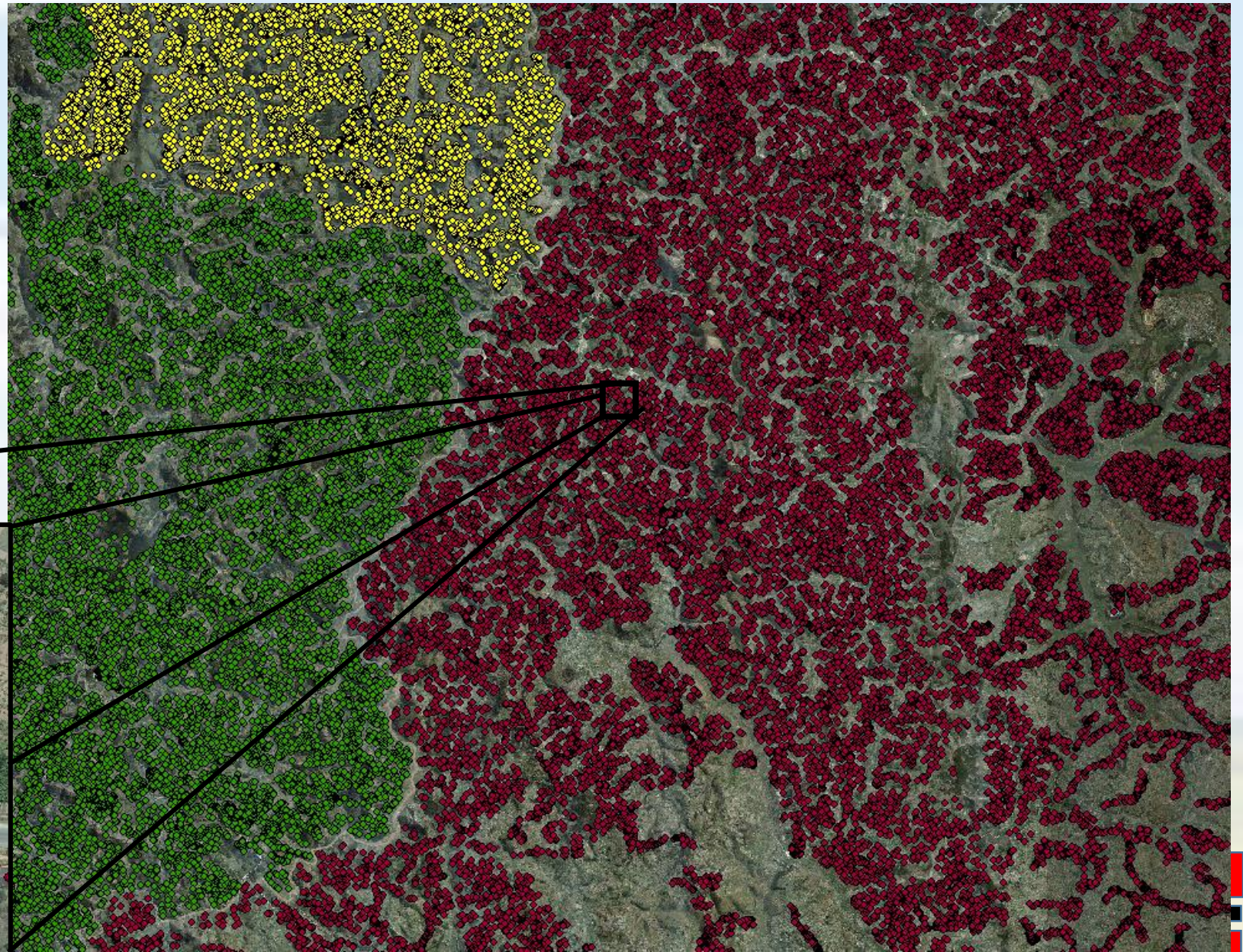


LOAD FORECAST METHODOLOGY

Capture Potential Customers AND LOAD GEOGRAPHICALLY

- Data is 5 years old. Data is extrapolated with population growth before use.

1. LOCATE POTENTIAL CUSTOMERS (LOAD)
2. NOW WHERE THE LOAD IS (Feeder, Substation)
3. SIMULATE LOAD TO IDENTIFY REINFORCEMENT REQUIREMENTS



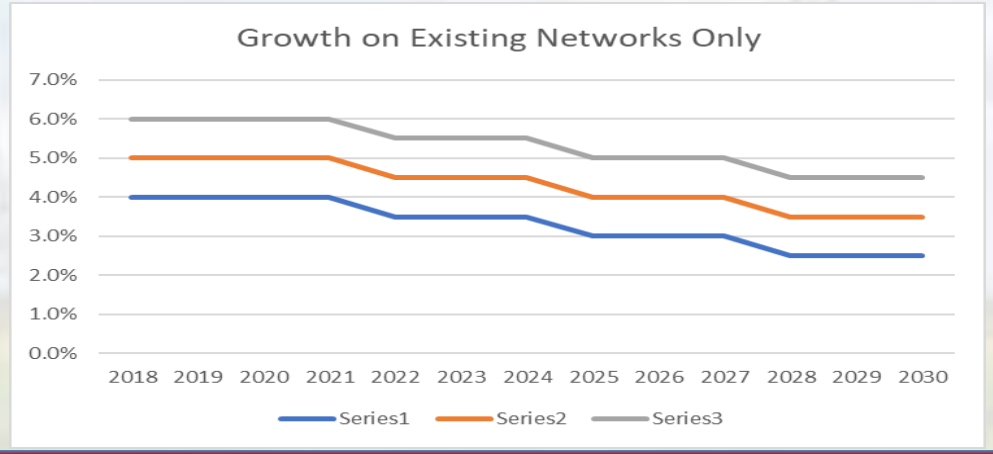
ASSUMPTIONS FOR LOAD FORECAST AND PLANNING

Assumptions

For the distribution planning, certain assumptions must be made to calculate load forecast.

- A target of 52% of all customers must be connected on-grid, the remaining 48% off-grid
- The population growth is taken at 3%. That implies that the target connections are growing every year with 3% and after 100% electrification, the population growth must still be catered for to maintain the 100%.
- The growth on existing load is divided into 3 categories for urban to rural load. This only represents the growth of existing networks and excludes new electrification and bulk loads.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Growth on Existing load LOW	0.0%	4.0%	4.0%	4.0%	4.0%	3.5%	3.5%	3.5%	3.0%	3.0%	3.0%	2.5%	2.5%	2.5%
Growth on Existing load MED	0.0%	5.0%	5.0%	5.0%	5.0%	4.5%	4.5%	4.5%	4.0%	4.0%	4.0%	3.5%	3.5%	3.5%
Growth on Existing load HI	0.0%	6.0%	6.0%	6.0%	6.0%	5.5%	5.5%	5.5%	5.0%	5.0%	5.0%	4.5%	4.5%	4.5%

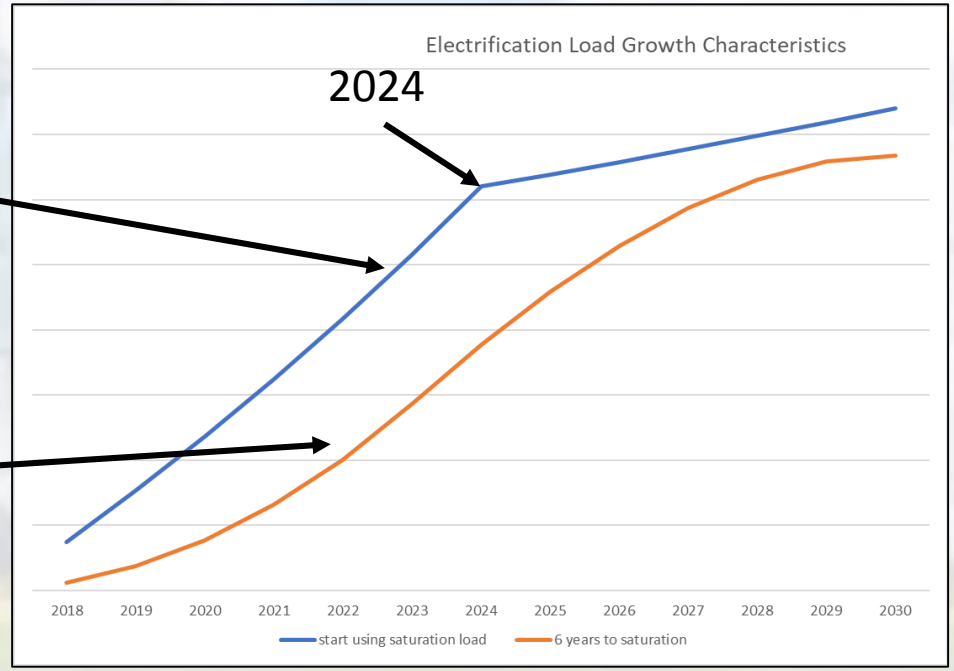


Assumptions (Continued)

- Individual households take 6 years from connection date to saturation load. In most African conditions, new connections do not take up full capacity at the time of connection, but it saturates after some time. Taking this into consideration will prevent unnecessary high forecast and wrong generation planning.
- The average saturation load of new connections after 6 years is 80W per household. (ADMD after Diversity Maximum Demand = 80W)

Initial Load at 100% (European model)

Initial Load saturates after 6 years (African model)



The same connections and ADMD used in two different ways.

Assumptions (Continued)

- Method of calculating potential electrification load:

The 48/52% rule for on-grid is used on average for all feeders.

1. Count number of households next to the feeder using GIS Functionality
2. Due to age of Orthophoto's data, add 3% growth from 2014 = 12%
3. Calculate 52% average on each feeder to be connected
4. Do load forecast applying the S-Curve characteristic using PowerFactory functionality.

TRANSMISSION NETWORK DEVELOPMENT

PREVIEW OF SHORT TERM NETWORK CONFIGURATION

SHORT TERM NETWORK CONFIGURATION

220kV Lines:

Mamba - Rwabusoro – Bugesera

- Generation at Mamba is at 220kV
- Access Generation can be exported on 220kV without transformation (reduce losses)

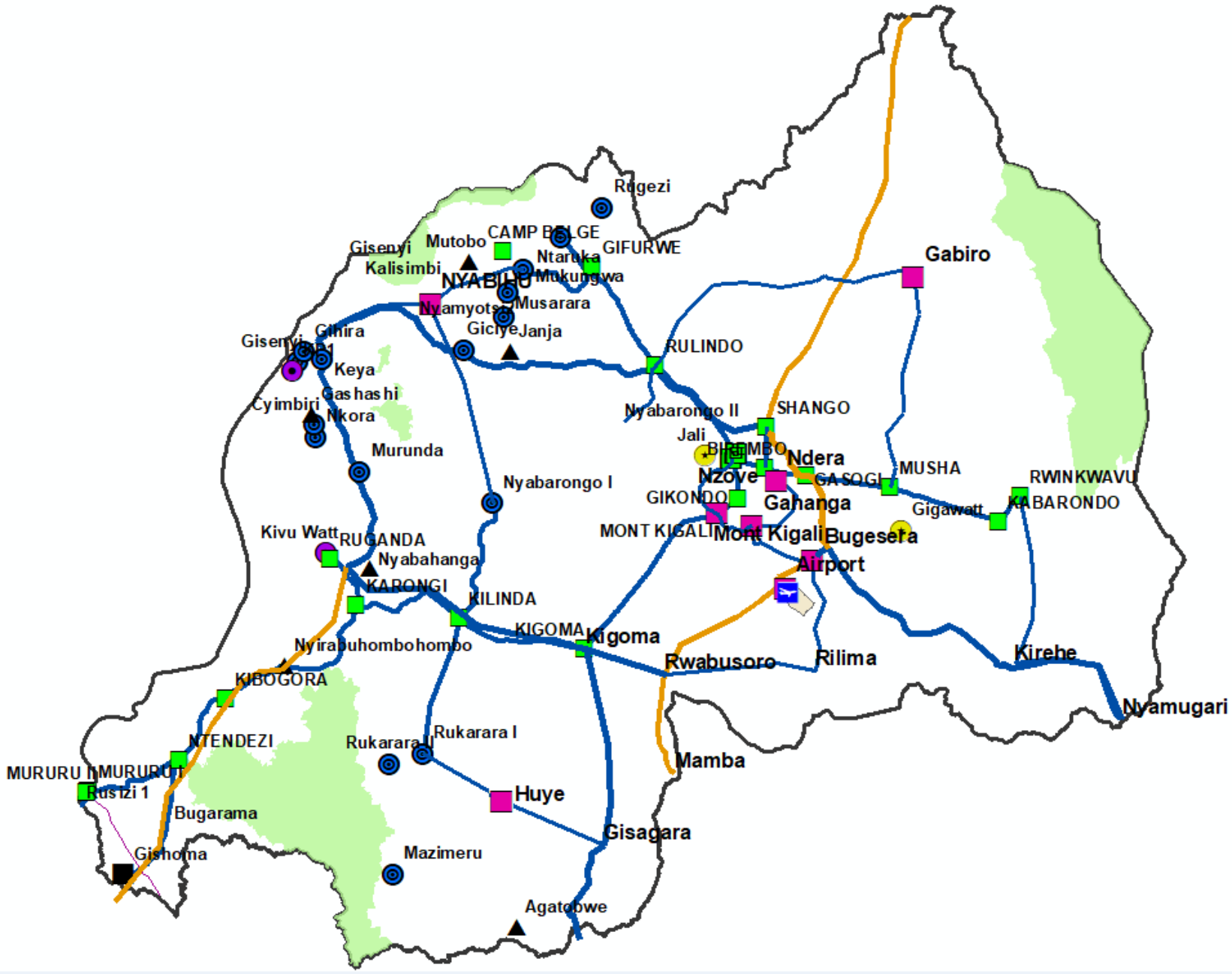
Rusumo/Nyamugari – Bugesera – Shango

- Supply at Rusumo is 220kV
- Interconnect with Shango – Uganda Network

220/110 Transformations:

Rwabusoro 220/110kV 93.8MVA
Bugesera 220/110kV 93.8MVA
Rubavu 220/110kV 93.8MVA
Bwishura 220/110kV 93.8MVA
Shango 220/110kV 93.8MVA

Note – Gisagara has no 220/110kV Trf. This must be installed before upgrade to 220kV

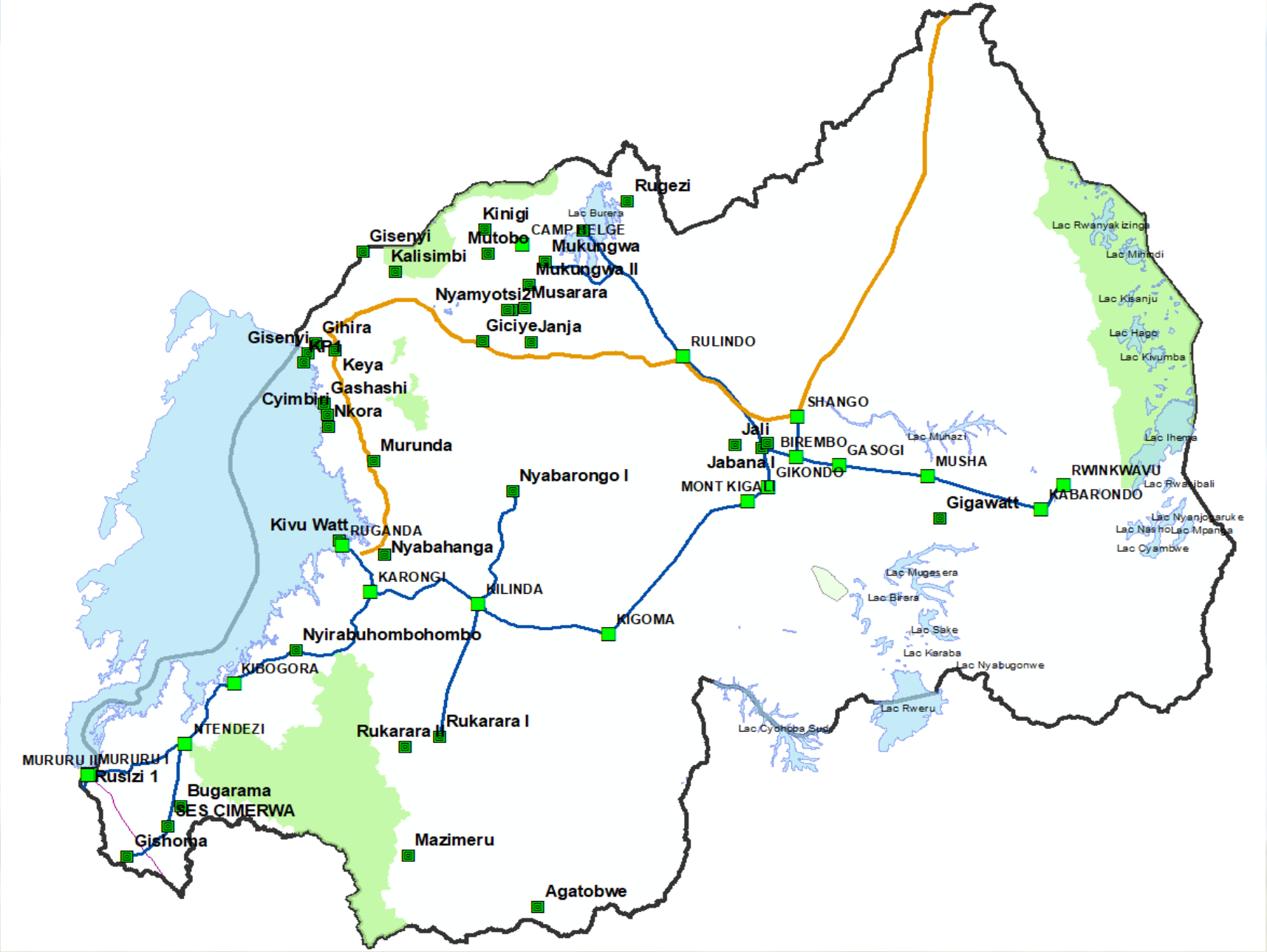


Existing Network (2017)

220kV Length=257(including the length from Shango to the border between Rwanda and Uganda)

110kV Length=552.4km

Alternators evacuating in HV Transmission Lines=27(including Rusizi II HPP Alternators)



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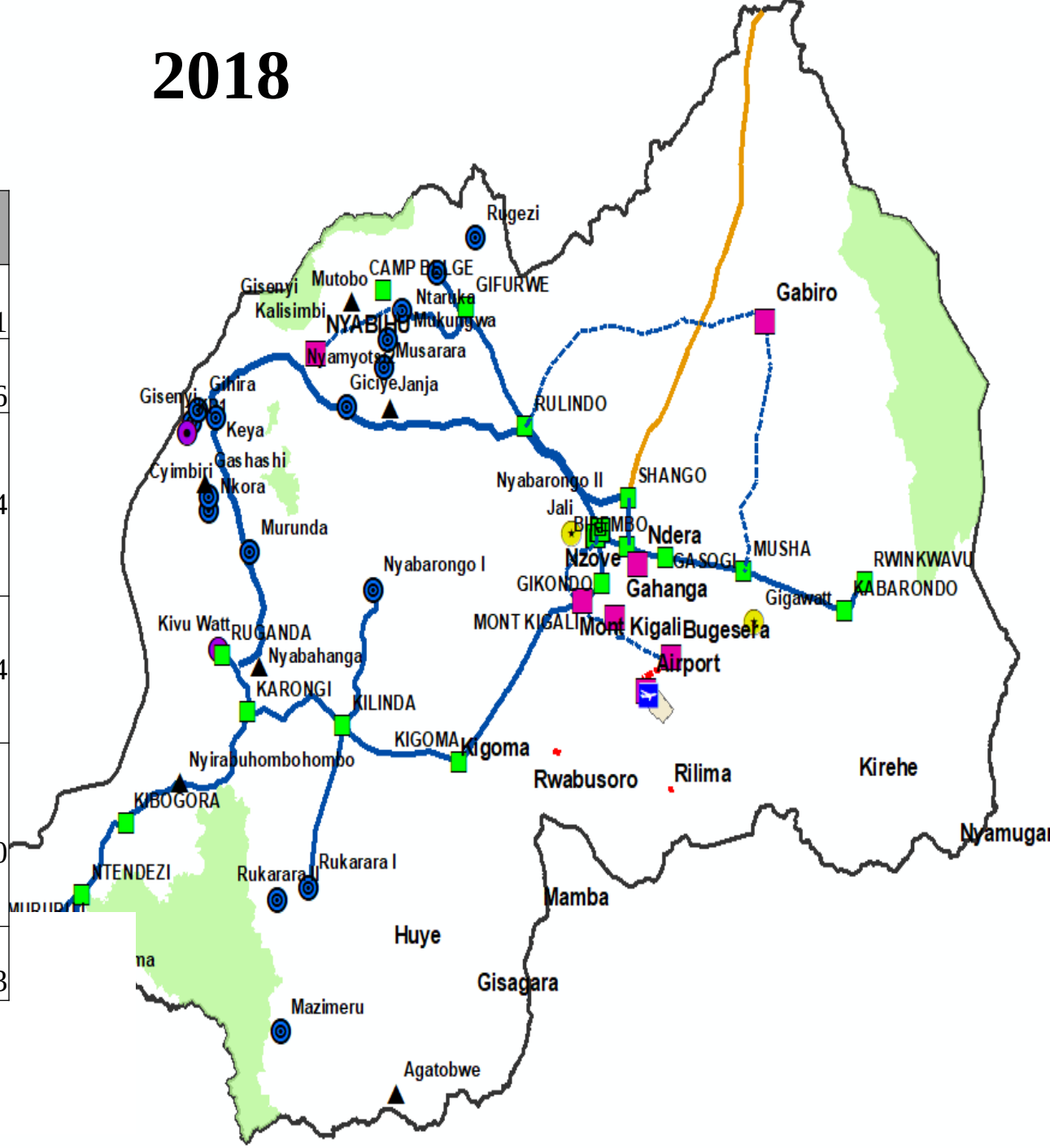
2018

Project Name	Project Component	Length/ Capacity	Estimated Cost(USD)
Gifurwe s/s	Upgrade of Gifurwe Substation	10	1,976,471
Rulindo s/s	Rehabilitation of Rulinda Substation	20	4,941,176
110kV single circuit Mukungwa-Nyabihu	1.Construction of Transmission line, 2.Construction of Musanze s/s,	29	5,442,254
Musha-Gabiro Rulindo 110kV line and Gabiro Substation	Upgrade Musha Substation, Construction of Gabiro Substation Construction of 110kV line	109.5	22,559,884
110kV single circuit Gahanga-Ndera at KSEZ	1. Construction of Transmission line, 2. Extension of Gahanga s/s, 3. Extension of Gasogi s/s	17.8	9,150,400
110kV Gahanga-Bugesera	Construction of Transmission Line	17.5	5,323,203



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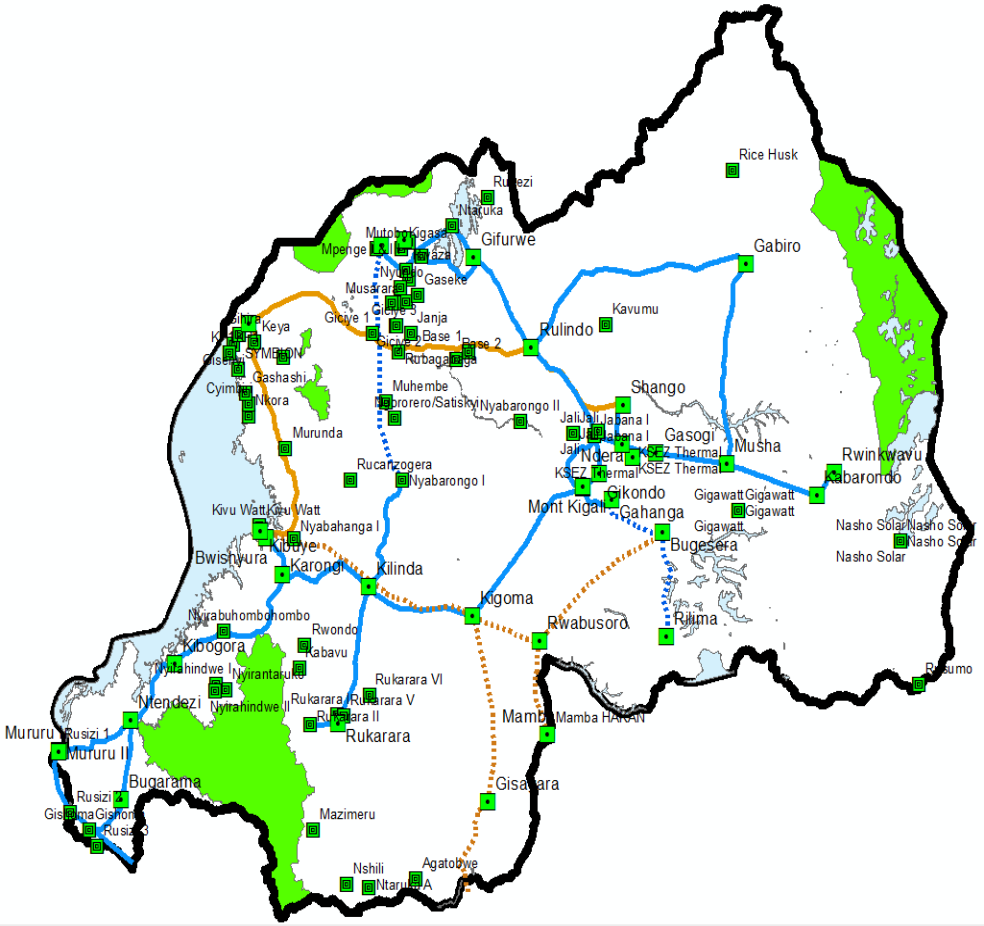
2019

Project Name	Project Component	Length (Km)	Project Cost(USD)	Project area and Impact
220kV Interconnector, Rwanda-Burundi/Kigoma-Gisagara-Burundi border	Construction of Transmission line,	64	19,601,008.70	Regional interconnection network towards power sharing and trade
220kV Bwishyura-Kigoma-Rwabusoro, upgrade of Bwishyura and Kigoma SS	1.Construction of Transmission line, 2.Extension & upgrade of Kigoma s/s 3.Construction of Rwabusoro s/s	74	34,285,835.29	To evacuate 25MW from Kivu watt phase I, 28MW from Nyabarongo I, 9MW from Rukarara will be put on transmission network on Kilinda s/s. With almost 10MW from SINELAC the existing 110kV line will no longer be able to carry all these 72MW. Later Kivu watt will be extended to give 75MW. This line will help to evacuate power from this incoming power plants.
220kV Mamba-Rwabusoro-Bugesera, Mamba Busbar and Rwabusoro SS	1.Construction of Transmission line 2.Construction of Mamba s/s 3.Extension of Bugesera s/s	73	48,090,400	To evacuate 80MW power from Hakan PPP to Rwabusoro.
110kV single circuit NyabarongoI –Nyabihu changed to Nyabarongo I-Musanze	1. Construction of Transmission line, 2. Extension of NyabarongoI s/s	55	12,680,067	To evacuate power from Nyabarongo I HPP
110kV single circuit Bugesera-Rilima initially will be operated on 30 kV within one year	1. Construction of Transmission Line 2.Construction of Rilima Switchgear	24	3,600,000	Supply of Bugesera network from Rwabusoro SS and N-1 for Bugesera Industrial Park
110kV Gahanga-Bugesera	Construction of Transmission Line	17.5	5,323,203	Strengthning of Bugesera SS



The size of 110kV Ntaruka-Mukungwa-Rulindo-Jabana-Birembo-Gasogi-Musha-Kabarondo-Rwinkwavu Will be upgraded from ACSR 157/25 to 240/40

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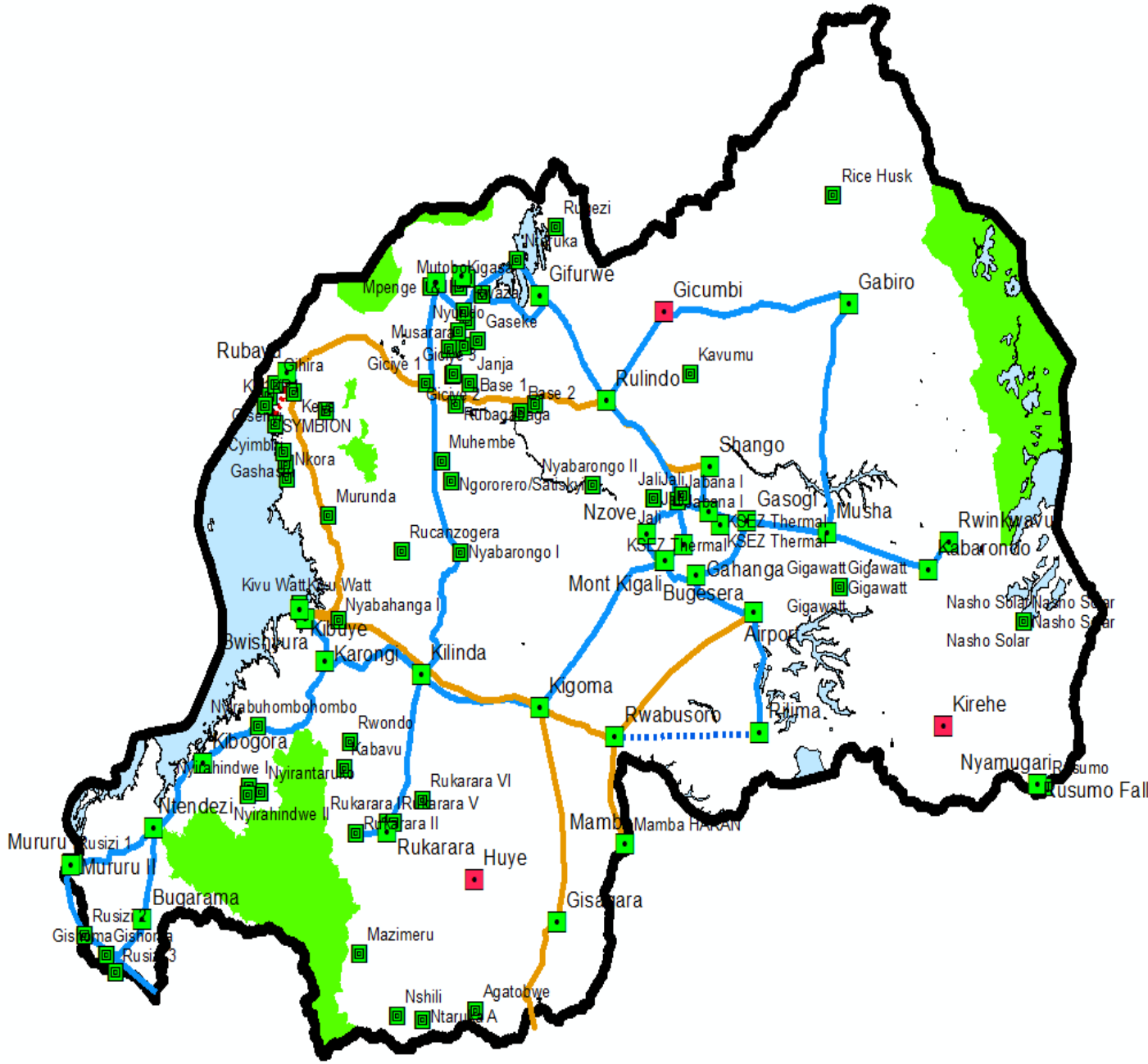
2020

Project Name	Project Component	Length (Km)/Capacity	Project Cost(USD)	Project area and Impact
110 kV Rwabusoro-Rilima	1. Construction of Transmission Line	32	4,800,000	Power Evacuation from Rwabusoro ss to Bugesera Airport
Rilima Substation (Industrial Park)	1. Construction of Substation	20	6,000,000	Supply Electricity in Bugesera Industry Park
Nzove Substation	1. Construction of Substation	30MVA	7,000,000	Supply 30kV at proposed Skol and WASAC industries. Hence network reinforcement



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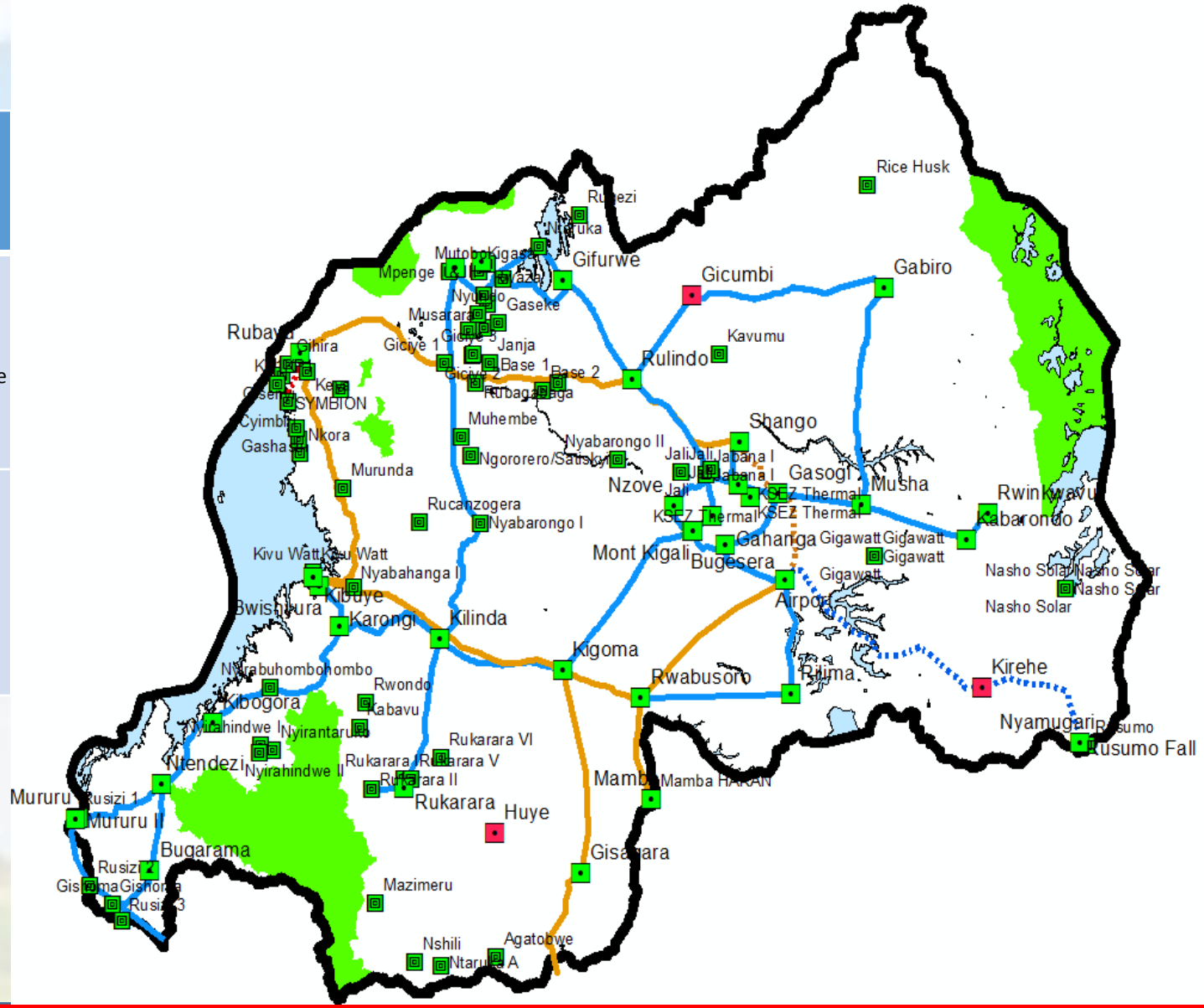
2021

Project Name	Project Component	Length (Km)	Project Cost(USD)	Project area and Impact
220kV single circuit Rusumo-Nyamugari and 110kV Nyamugari-Bugesera-Shango	1. Transmission line, 2.Construction of Bugesera s/s	114	40,050,730.16	To evacuate 26.7MW power from Rusumo falls HPP to Shango via Bugesera. The substation will supply the incoming Bugesera Airport, Bugesera Industrial zone via Rilima ss and reinforce the distribution network in the area. The substation will receive 3 main feeders, Rusumo, Shango and Rwabusoro.
110kV single circuit Gahanga-Gasogi	1. Construction of Transmission line, 2. Extension of Gahanga s/s, 3. Extension of Gasogi s/s	17.8	9,150,400	110kV Network renforcement & strengthening in Kigali city



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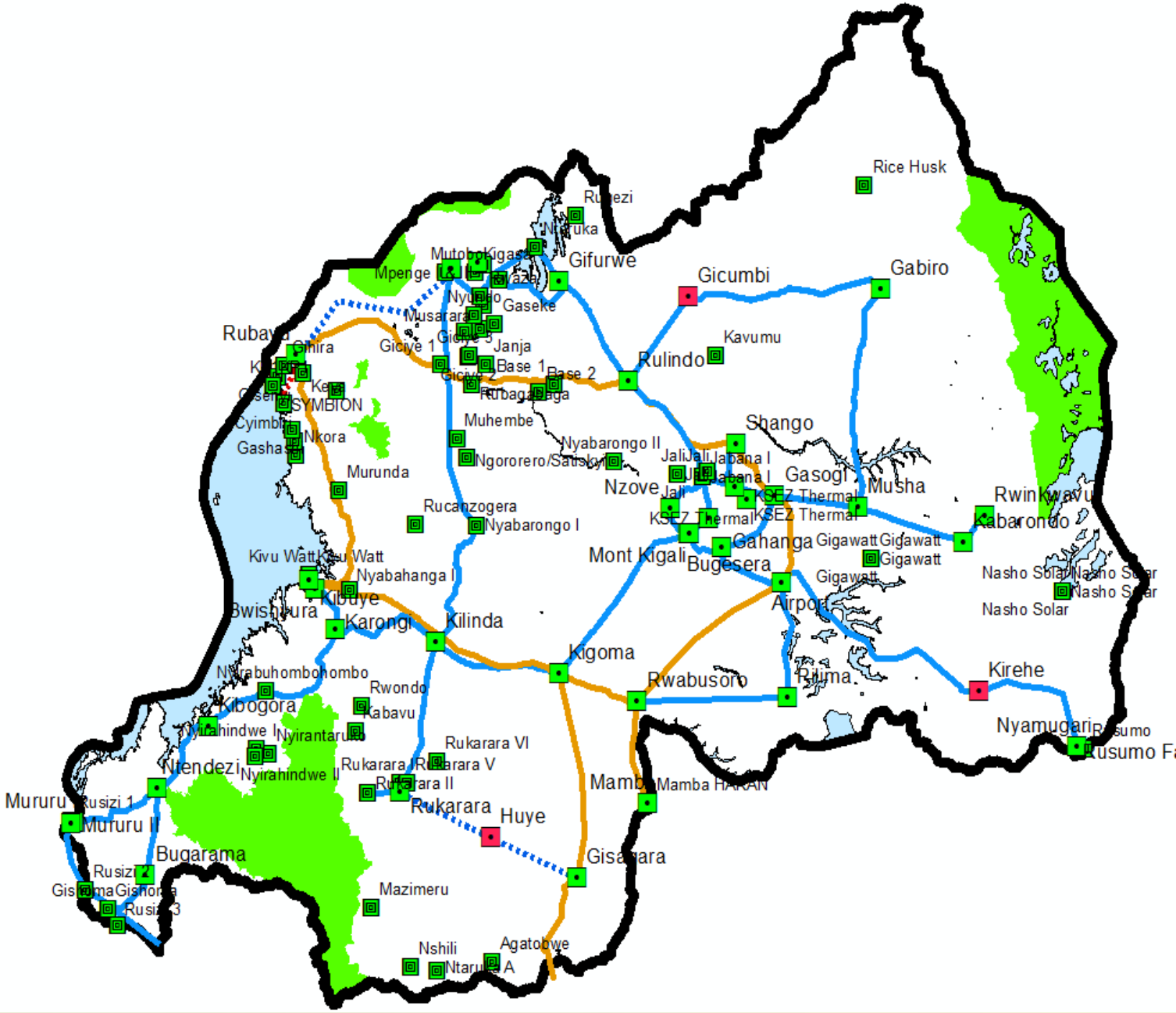
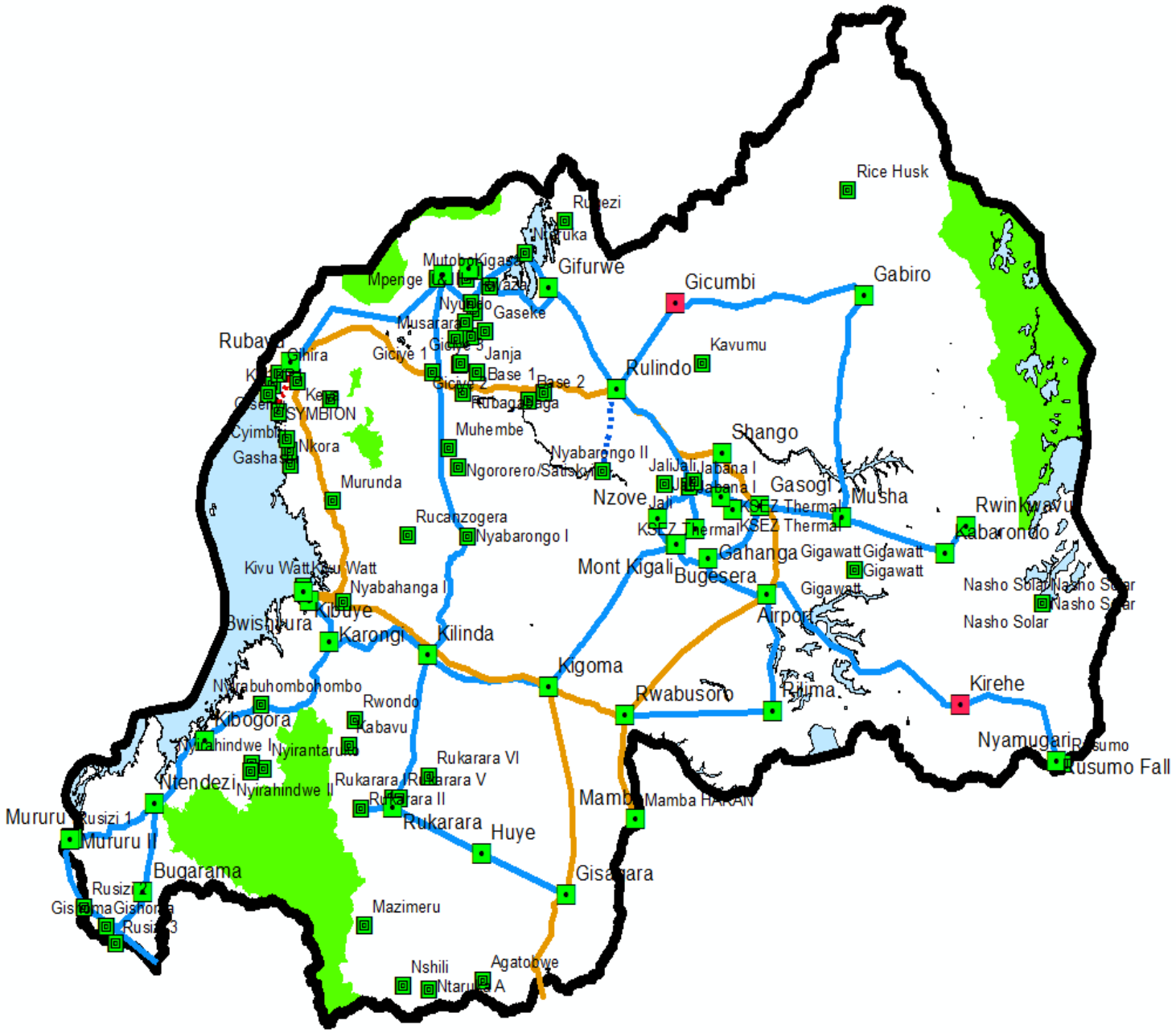
2022

Project Name	Project Component	Length (Km)	Project Cost(USD)	Project area and Impact
110kV single circuit Nyabihu - Rubavu will be changed to Musanze-Rubavu	1. Construction of Transmission Line	40	9,244,444	Strengthening of the high voltage network in the Nyabihu and Rubavu areas
110kV single circuit Rukarara-Huye-Gisagara	1. Construction of Transmission line, 2. Extension of Rukarara s/s, 3. Construction of Huye s/s	40.71	15,025,700	To evacuate the power to be generated by Rukarara HPPs and network sterngthening



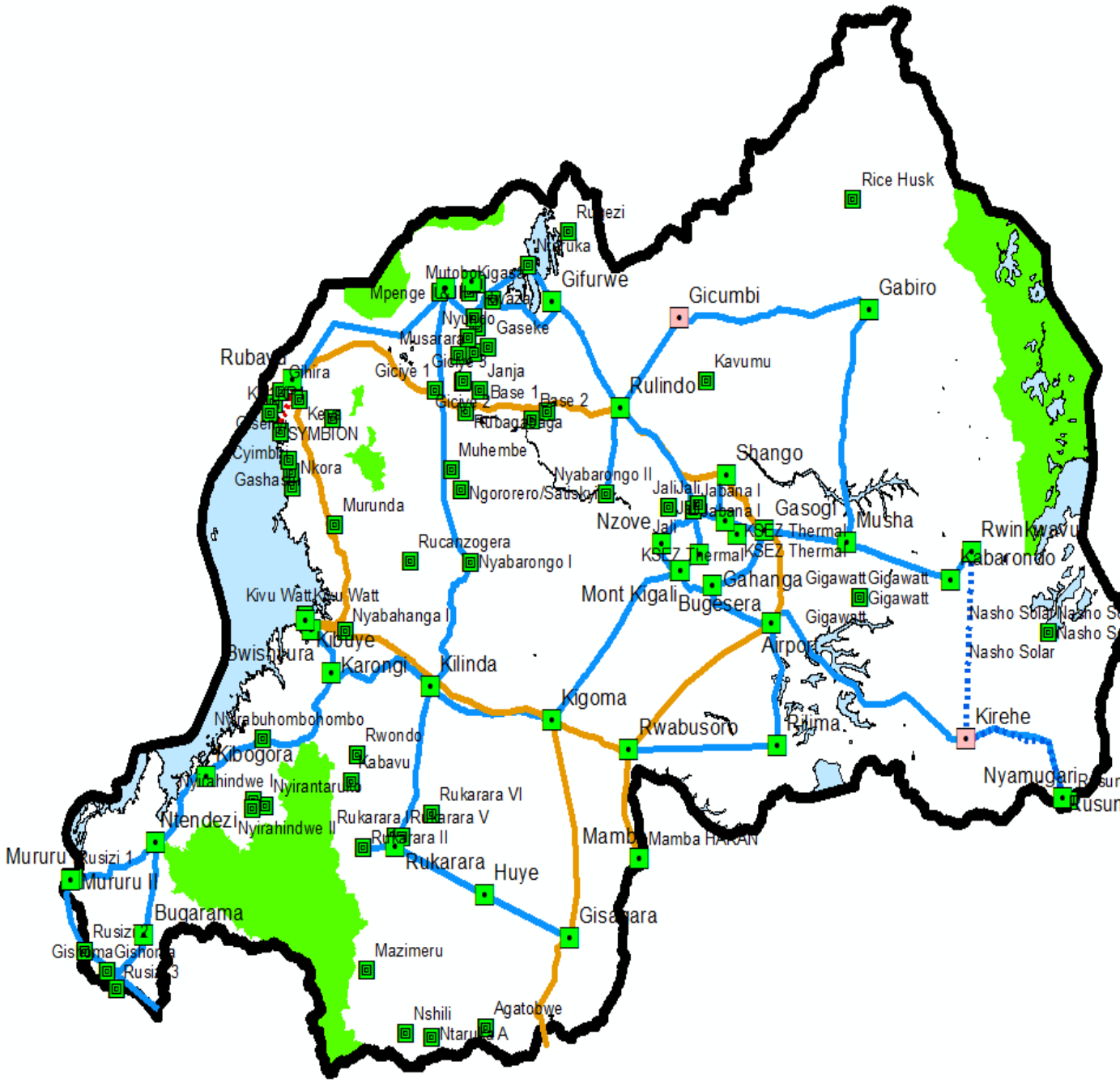
2023

Project Name	Project Component	Length (Km)	Project Cost(USD)	Project area and Impact
110kV single circuit Nyabarongo II-Rulindo	1. Construction of Transmission line, 2. Construction of NyabarongoII s/s 3. Extension of Rulindo s/s	16.64	14,874,240	TL will evacuate Nyabarongo II to Rulindo substation



2024

Project Name	Project Component	Length (Km)	Project Cost(USD)	Project area and Impact
110kV single circuit Rwinkwavu-Kirehe-Nyamugari (Rusumo)	1. Construction of Transmission line, 2. Upgrade of Rwinkwavu s/s, 3. Construction of Kirehe s/s, 4. Construction of Nyamugari s/s	89.07	23,719,500	110kV Network renforcement & strengthening in Kirehe District
GICUMBI SS	1. Construction of Substation	30	7,300,000	Network renforcement & strengthening in Gicumbi District
220kV Double circuit Symbion-Rubavu	1.Construction of Symbion substation 2.Construction of evacuation line	10.5	177,000,000	Evacuation of Power from Symbion MPP



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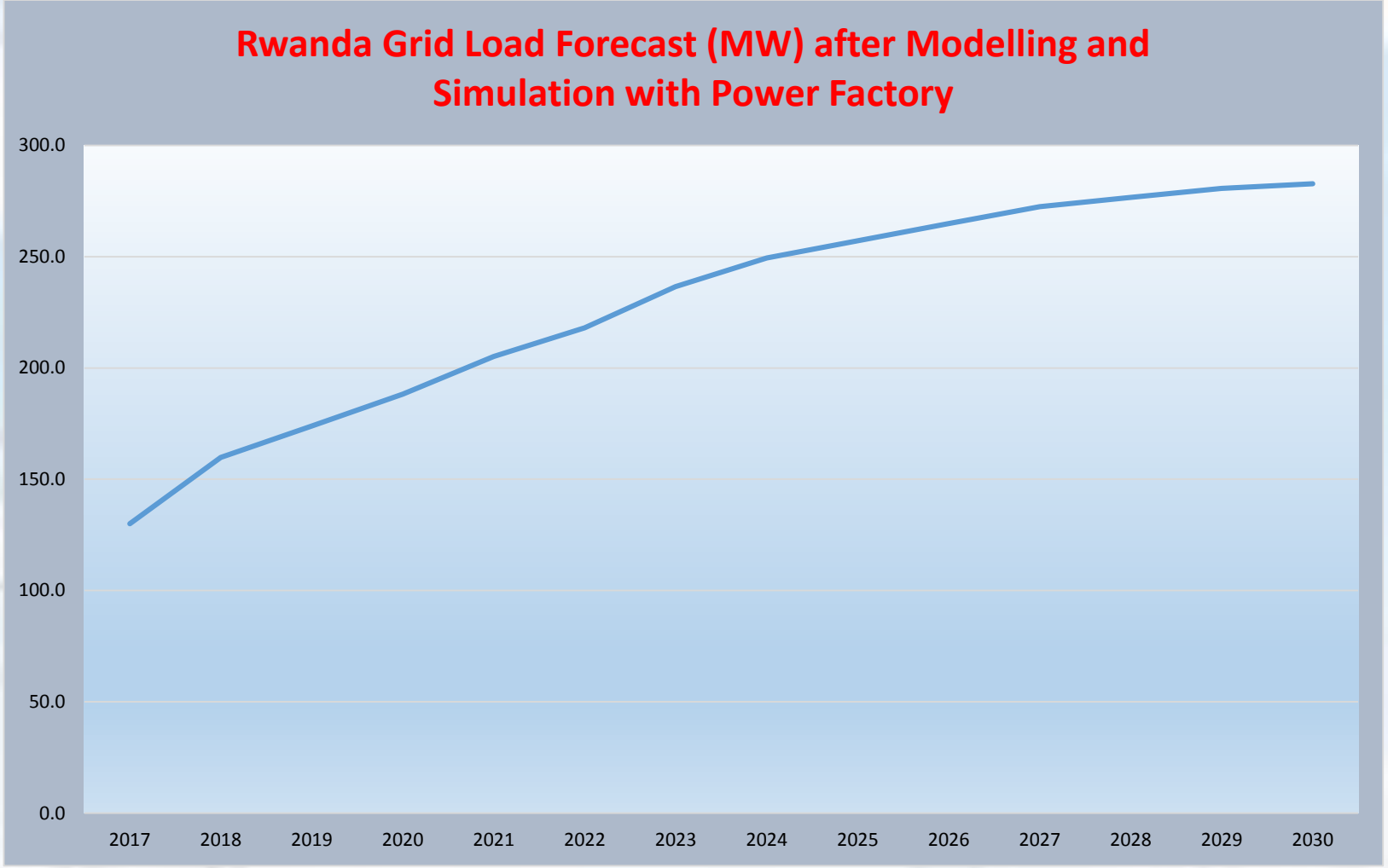
Rwanda Grid Load Forecast (MW) after Modelling and Simulation with Power Factory



Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Peak demand (MW)	130.0	159.7	173.9	188.2	205.1	218.0	236.5	249.5	257.2	264.9	272.5	276.6	280.7	282.7

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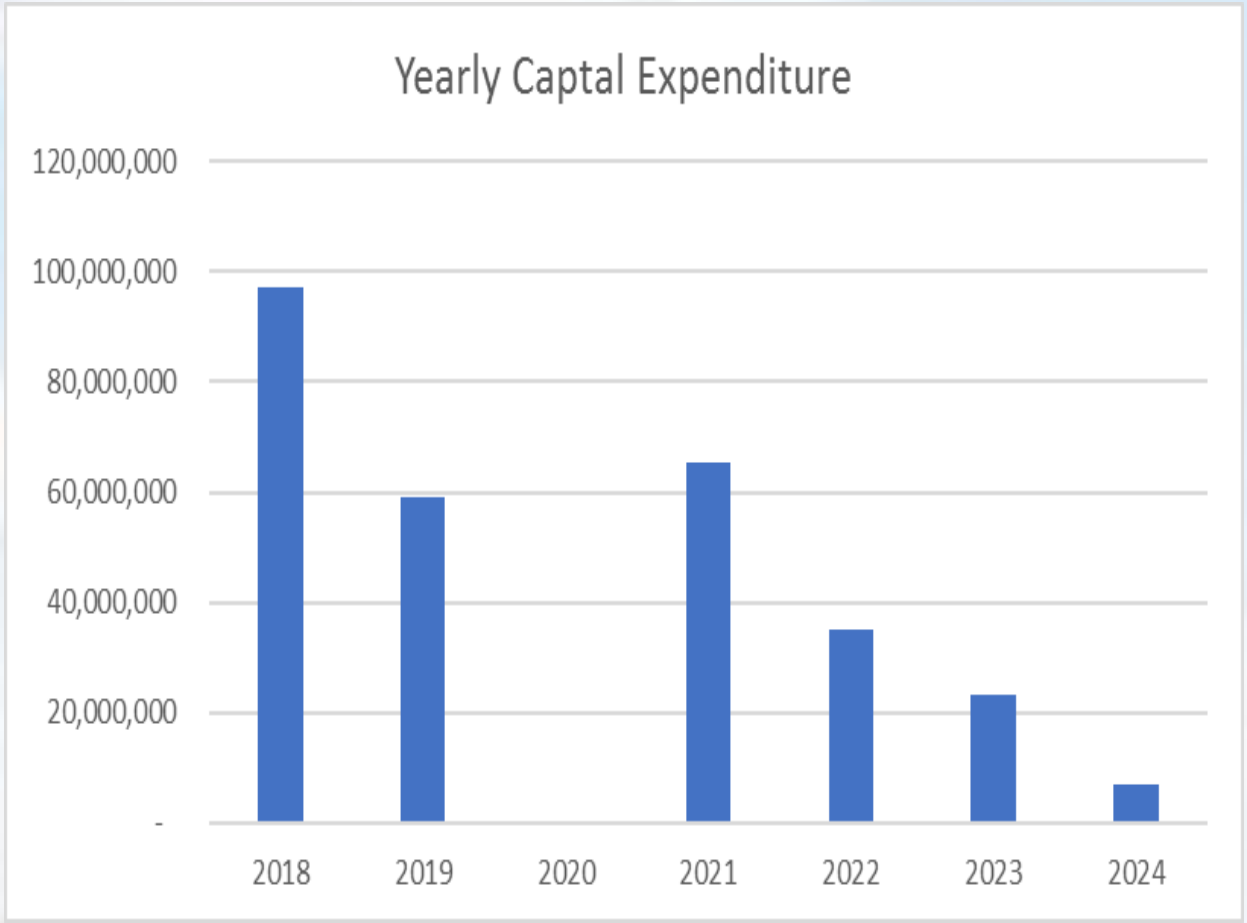

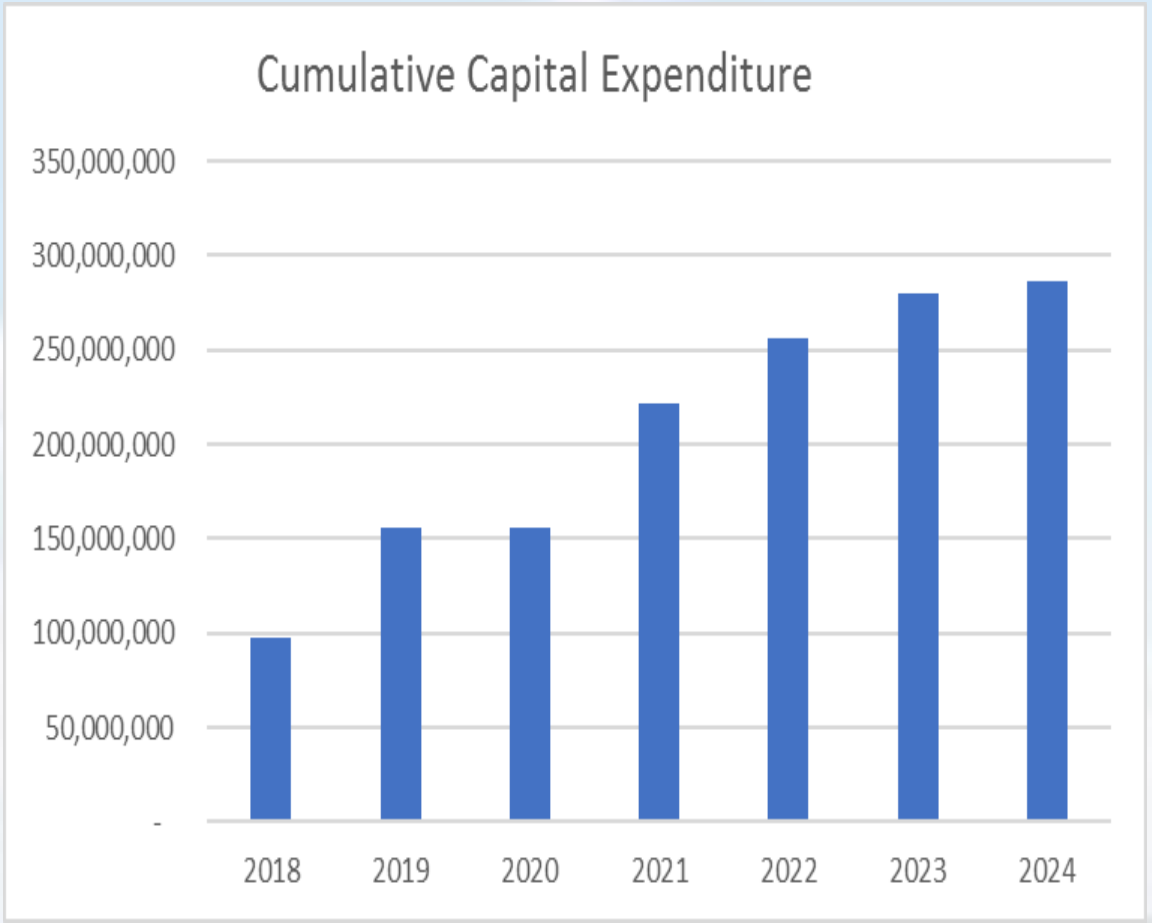

	Rilima(Industrial Park)	Transmission Line		4,320,000	Rwabusoro SS and N-1 for Bugesera Industrial Park	
3	110kV single circuit Nyabarongo I-Musanze	1. Construction of Transmission line, 2. Extension of NyabarongoI s/s	55	16,900,000	To evacuate power from Nyabarongo I HPP	2019
5	Nyamugari Substation	Construction of Nyamugari Substation	20/75MVA	12,000,000	Strengthening of Eastern Network and it will help to transmit 27MW from Rusumo to Nyamugari(220kV Line) then From Nyamugari to Bugesera(110kV Line)	2021
6	110kV single circuit Rwinkwavu-Kirehe-Nyamugari (Rusumo)	1. Construction of Transmission line,	89.07	27,032,600	110kV Network renforcement & strengthening in Kirehe District	2021
		2. Upgrade of Rwinkwavu s/s,				
		3. Construction of Kirehe s/s,				
7	110 kV single circuit Rwabusoro-Rilima	1. Construction of Transmission Line	32	5,760,000	Power Evacuation from Rwabusoro ss to Bugesera Airport	2019
8	110/30 kV Rilima Substation(Industrial Park)	1. Construction of Substation	20	13,665,551	Supply Electricity in Bugesera Industry Park	2019
9	Shango Control Center	1. Construction of control center			To assist existing control center	2019
10	Nzove Substation	1. Construction of Substation	20MVA	7,000,000	Supply 30kV at proposed Skol and WASAC industries. Hence network reinforcement	2019
11	Re-Conducting of 110 kV Tline from Ntaruka Ss to Rwinkwavu Ss	1. Rehabilitation of Transmission Line	191.72	11,311,480	Loss reduction and Netwok stability	2019
12	220kV Symbion-Rubavu	1.Construction of Transmission line 2.Construction of Symbion Substation	10.5	19,890,000	Evacuation of power from Symbion MPP	2022
13	110kV single circuit Gahanga-Ndera at KSEZ	1. Construction of Transmission line, 2. Extension of Gahanga s/s, 3. Extension of Gasogi s/s	17.8	15,204,000	110kV Network renforcement & strengthening in Kigali city	2018
14	110kV single circuit Musanze-Rubavu	1. Construction of Transmission Line	40	7,200,000	Strengthening of the high voltage network in the Nyabihu and Rubavu areas	2021
15	110kV single circuit Rukarara-Huye-Gisagara	1. Construction of Transmission line, 2. Extension of Rukarara s/s, 3. Construction of Huye s/s	40.71	19,327,800	To evacuate the power to be generated by Rukarara HPPs and network strengthening	2021

16	110kV single circuit Nyabarongo II-Rulindo	1. Construction of Transmission line, 2. Construction of NyabarongoII s/s 3. Extension of Rulindo s/s	16.64	14,995,200	TL will evacuate Nyabarongo II to Rulindo substation	2022
17	220kV single circuit Bwishyura-Kamanyora	1. Construction of Transmission Line	89.07	23,158,200	Regional power network interconnection towards power sharing amongest EAC countries	2023
18	GICUMBI SS	1. Construction of Substation	20	7,000,000	Network renforcement & strengthening in Gicumbi District	2024
19	Gifurwe s/s	Upgrade of Gifurwe Substation	10MVA	1,976,471	Network Reinforcement	2018
20	Rulindo s/s	Rehabilitation of Rulinda Substation	20	4,941,176	Network Reinforcement and flexibility to construct new lines	2018
21	110kV single circuit Mukungwa-Nyabihu	1.Construction of Transmission line, 2.Construction of Mukungwa s/s,	29	5,442,254	To evacuate 12MW from Mukungwa and Ntaruka once the old 110kV is faulty or under repair. It will help to connect the existing 110kV line with incoming 110kV line. Nyabihu substation will receive 3 main feeders; Gisenyi, Mukungwa and Nyabarongo1.	2018
22	110kV Single Circuit Musha-Gabiro Rulindo 110kV line and Gabiro Substation	1.Upgrade Musha Substation 2.Construction of Gabiro Substation 3.Construction of 110kV line	109.5	22,559,884	Network Reinforcement	2018
23	220kV Double Circuit Mamba-Rwabusoro-Bugesera	1.Construction of Mamba, Rwabusoro and Bugesera Substations 2.Constructuion of Line	60	43,982,829	1.Evacuation of 80MW from Hakan 2.It will serve in Interconnection network	2018

RECOMMENDATIONS

- The size of 110kV Ntaruka-Mukungwa-Rulindo-Jabana-Birembo-Gasogi-Musha-Kabarondo-Rwinkwavu Will be upgraded from ACSR 157/25 to 240/40
- The 220kV Bugesera-Shango Transmission Line Shall be constructed before 2020 in order to have a significant improvement of voltage at Shango Substation and it will help to operate the 220kV Bwishyura-Rubavu-Shango under 110kV in the 10 years future from now.
- To install needed transformers at the following substations:
  - Rubavu 110/30kV 31.5MVA
  - Bwishura 110/30kV 31.5MVA
  - Shango 110/30kV 31.5MVA
  - Nyamugari 220/110kV 75MVA

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Thank You