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Automatic Restoration of the Network by using Distributed Energy Sources

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Abstract**:** ***Now-a-days power outage is a big problem. The grid operators cannot control the power flow from grid to the consumers. Even though many changes have been done in the power system there still exists power outages and grid operators could not guarantee the continuous power flow. In this context this paper deals with the rerouting of lines is done when there is a fault in a line. The same is happened in the case of a generator, Distributed Generators (DGs) are used. DG is a generator which is run on Biomass, small hydro or any gas station. DGs are only few MW and serve only when main generator is out of service. These generators are located near the load centre. The same concept is incorporated in this paper and the software used here is the Power World simulator. This paper deals with the normal 6 bus system and it is also applied for RBTS IEEE 6 bus system by using power world simulator.***

Index Terms**:** ***Distributed generators, power world simulator, RBTS IEEE 6 bus system, rerouting.***

I. INTRODUCTION

Many changes have been done in power transmission system constructions and these are done to have continuous power flow between generation station and consumers. But this is a big task. So to avoid power diversification and also to have reliability in the network some measures are taken in the transmission network. By employing some grid operating measures like discreet operation guidelines, employing distributed generations and applying Islanding mode of operation the grid can be operated to almost perfect conditions. But even though having taken many precautions there still exists some problems in the network such as discontinuous power flow, overloading of transmission lines etc.

In order to avoid these problems some procedures have to be followed such as rerouting of power by using relays and by decoupling the transmission line from the faulty area. As the demand for uninterrupted power flow have been increased, there increased the demand for usage of DGs and remote controlled circuit breakers (CBRs).

A. Active power networks

To have automatic restoration of the network, the system should have mesh type configuration. Some says that Mesh type of configurations are very complex, dangerous as there is possibility of bidirectional power flow and are also costly. But some studies have been done saying that these networks are flexible and more secured. Some communication links along with control schemes are incorporated in the network so that the DGs which are installed in the grid work as 'fit and forget' policy.

A. *Distributed Generators*

Installations of DGs have been increasing as they serve as backup power when the main generators fail to work. They work when there is a need of excessive power, when there is a transmission line congestions etc. DG's can improve power quality of a network by inducing voltage sags caused due to long transmission line and due to mismatching of phase angle between loads and generations. This makes sure that there is uninterrupted power supply to the consumers.

B. Automatic restoration of network

Automatic restoration of a network is nothing but whenever a fault occurs in the network, the system should automatically restore to its normal condition by itself. This has to be done for every fault in the network. For example, if there is a fault in a line the power should be directed through other line and when a generator fails to supply load the other generators automatically take over the loads.

II. POWER WORLD SIMULATOR (PWS)

An event or circumstance that occurs and which is not predictable is called contingency. Contingency can occur in power system due to outage of a transmission line, a generator and a closure of normally opened transmission line. When a outage occurs then there will be overloading in the other parts of the generator or transmission line. It may leads to voltage drop or rise in the power system. Contingency analysis is used to study or know these changes in the power system.

Power world simulator helps in designing and simulation of a network. It is software that is used to analyze the real time data. It uses computer program that deals with the operation of electrical systems. This software is used to test any overloading in the system. This is usually called as "system security". To test the network live on grid would cause damage to the network. So the overloading or any other rerouting is checked on the software and then it is implemented on the grid directly. PWS has many tools for studying contingencies. Contingency elements that can be done in PWS are opening/closing of a transmission line, adding or removing of a transmission line, generator load, switched shunt MWs or MVAs and the values of these can also be changed.

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III. TESTING OF 6 BUS SYSTEM

A 6 bus meshed connected system is designed in PWS. In this network it has two thermal generators and two distributed generators. Thermal generators are rated as 630MW and 230MW respectively. And the DGs are rated as 200MW each respectively. The network has loads which are inductive. These are connected through bus bars. Each bus bar is given different resistances, reactance and line lengths values so that rerouting can be made easy. The power flow in the network is solved by PWS software. Due to overloading of the network, the devices may work beyond their ratings.

A. Network working under normal conditions:

Under normal conditions the total load of 700MW is supplied by the two thermal generators which are together generating 830MW of power. This power will be supplying the load demand and also the transmission power losses in the lines. At this stage lines 1 to 2 and 2 to 4 are transmitting more power than they are capable of. The other two generators which are DGs are not generating any power because there is enough power to meet the load demand in the system.

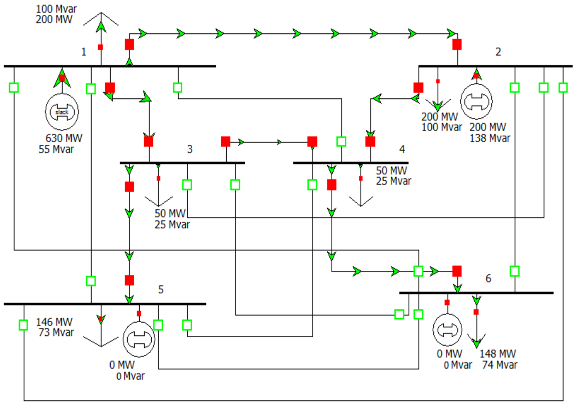

Fig. 1(a) Normal operation of the power system

The figures 1(b) and 1(c) depicts the branch and generators records which are obtained after solving in PWS.

	Number of Bus	Name of Bus	ID	Status	Gen MW	Gen Mvar	Set Volt	AGC	AVR	Min MW	Max MW	Min Mvar	Max Mvar	Cost Model	Part. Factor
1	1	1	1	Closed	732.00	165.49	1.00000	NO	YES	404.00	1000.00	-9900.00	9900.00	None	10.00
2	2	2	1	Closed	117.27	212.53	1.00000	NO	YES	456.00	1000.00	-9900.00	9900.00	None	10.00
3	5	5	1	Open	0.00	0.00	1.00000	NO	YES	300.00	1000.00	-9900.00	9900.00	None	10.00
4	6	6	1	Open	0.00	0.00	1.00000	YES	YES	0.00	1000.00	-9900.00	9900.00	None	10.00

Fig. 1(b) Generator records under normal conditions

All the six loads present at the six bus bars will be met by the thermal generators 1 and 2 only. The load at the bus bar 3 is met and the power is flowing from the transmission lines 1 to 3. To meet the load at bus bar 4, the second thermal generator generates the power and here the power is flowing from the transmission line 2 to 4. The load at the bus bar 5 the power flow will be from the transmission lines 1 to 3 and 3 to 5. For the load at bus bar 6, the power flow will be from transmission line 2 to 4 and 4 to 6.

	From Number	From Name	To Number	To Name	Circuit	Status	Branch Device Type	Xfrmr	MW From	Mvar From	MVA From	Lim MVA	% of MVA Limit (Max)	MW Loss	Mvar Loss
1	1	1	2	2	1	Closed	Line	NO	243.9	-40.2	247.1	0.0	0.0	12.14	38.56
2	1	1	3	3	1	Closed	Line	NO	288.1	105.7	306.9	0.0	0.0	19.05	67.35
3	1	1	4	4	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00
4	1	1	5	5	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00
5	1	1	6	6	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00
6	3	3	2	2	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00
7	4	4	2	2	1	Closed	Line	NO	-144.3	-24.3	146.3	0.0	0.0	4.74	9.49
8	5	5	2	2	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00
9	2	2	6	6	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00
10	3	3	4	4	1	Closed	Line	NO	63.9	-89.8	110.2	0.0	0.0	2.97	3.53
11	3	3	5	5	1	Closed	Line	NO	155.2	103.1	186.3	0.0	0.0	9.20	30.07
12	3	3	6	6	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00
13	4	4	5	5	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00
14	4	4	6	6	1	Closed	Line	NO	155.2	-94.0	181.4	0.0	0.0	7.18	19.23
15	5	5	6	6	1	Open	Line	NO	0.0	0.0	0.0	0.0	0.0	0.00	0.00

Fig. 1(c) Branch records under normal conditions

B. Generator connected to bus 1 out of service

In this network we can see that generator connected to bus bar 1 is out of service. So to serve the load connected at the bus bar 1 generator connected at bus bar 2 is supplying power. But the transmission lines between bus bar 2-1 and 2-4 are overloaded. These two transmission lines are transmitting power more than their rating. So there should be another line that has to transmit the power.

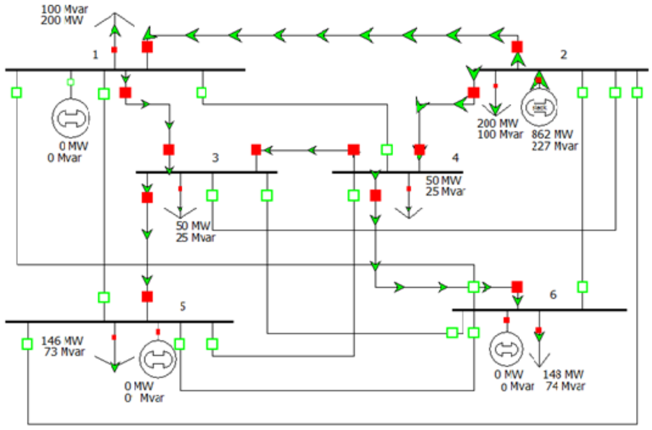

Fig. 1(d) Network operation when generator 1 out of service

C. Transmission line out of service

In this case the line from 1 to 2 is open and the power flow path is diverted to the path 2 to 4. Here we can see that there is overflow in the line and so the power is rerouted to other line i.e., 1 to 4. In the normal operation the power flow is from 3 to 4 but when there is a fault in the line 1 to 2 power flow in the reverse manner that is from 4 to 3.

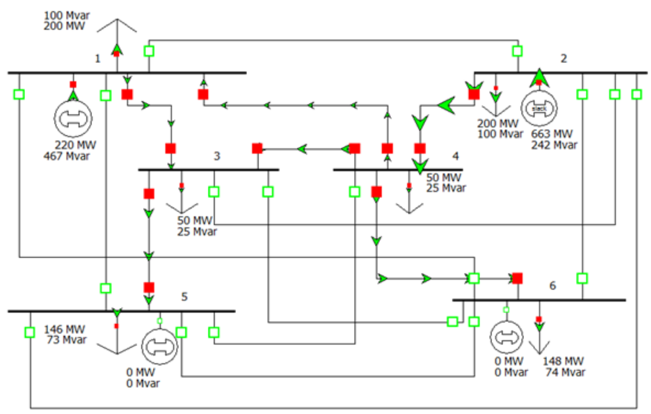

Fig. 1(e) Fault in the transmission line 1 to 2

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D. Generator and transmission out of service

It can be seen from the figure 1(f) that the generator 1 and the transmission line 1 to 2 both are in contingency. The total power has to be supplied by the generator 2 but this not possible. To meet the load DG's are connected. The load at the bus bar 5 is high than that of 6, DG at the bus bar 5 is connected to the grid. So both the thermal generator and the DG are supplying power.

But even though DG is working the thermal generator connected at the bus bar 2 is producing more power and therefore the transmission line connected between the bus bar 2 and 4 is over rated. This may damage the line. As the line 1 to 2 is open the load connected at the bus bar 1 is supplied power from generator 2. For this power is flowing from 2 to 4 and from there 4 to 1. When the two main generators are out of service then the two DGs produce the power required for the network. But this is not possible practically because the DGs are low rated and they work only as a backup not the main input source for the whole network. DGs can work along with the main generators only.

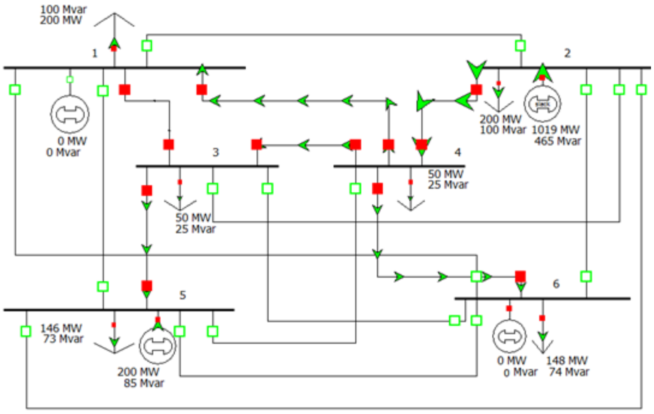

Fig. 1(f) Power flow in the network with generator 1 and line 1 to 2 out of service

E. Restore line fault using rerouting method

It is the method of rerouting the power from one transmission line to the other. Choosing of other line would be a trial and error method. The other line is chosen to avoid overload of the former line and it is picked up by satisfying all the objectives and constraints of the network. It says that the power is diverted from one path to the other path, but closing all other lines connected to that bus bar is not done. Closing of all other transmission lines would disturb main objective of the network. This would reduce the optimal costs of the network and also losses are reduced.

In the present scenario, we can see that the basic operation of the normal 6 bus system is it transmits the power from line connected between bus bar 1 and 2 and at this point this line is over rated. So to avoid this, the transmission connected between the bus bar 1 and 4 is closed. So power is diverted from the line 1-2 to line 1-4. By this over flow of power can be reduced in the transmission lines. This can be done with any of the lines provided if they are over rated and there exists another line connected between the generator and the load.

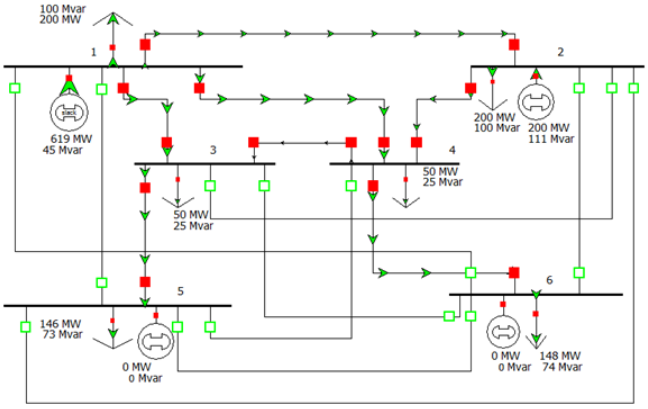

Fig. 1(g) Power flow in rerouting method

F. Analysis of losses from all the cases

By seeing the table I the losses during different cases can be analyzed. The transmission lines have different losses when there are changes in the network.

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Table I

lines	MW losses				MVAR Losses				MVA losses			
	Normal operation	When generator 1 is open	When line 1 to 2 is open	When both generator and line 1 to 2 open	Normal operation	When generator 1 is open	When line 1 to 2 is open	When both generator and line 1 to 2 open	Normal operation	When generator 1 is open	When line 1 to 2 is open	When both generator and line 1 to 2 open
1 to 2	243.9	298.7	0	0	40.2	23.1	0	0	247.1	299.6	0	0
1 to 3	288.1	98.7	210.6	3	105.7	76.9	15	76.5	306.9	125.1	211.1	76.6
1 to 4			212	198.8			20.7	41.2			213	203
4 to 2	144.3	317.1	0.1	657.3	24.3	64.1	22.8	272.8	146.3	323.5	22.8	711.7
3 to 4	63.9	109.5	0.4	213.6	89.8	2.6	10.6	130.7	110.2	109.5	10.6	250.4
3 to 5	155.2	154.2	151.3	155.2	103.1	112	55.2	233.1	186.3	190.6	161	280.1
4 to 6	155.2	154.9	153.3	160.6	94	88.8	50.1	243.5	181.4	178.5	161.2	291.7

Table I Analysis of losses in lines for different cases in 6 bus system

IV. RBTS IEEE 6 BUS SYSTEM

RBTS IEEE 6 bus system has six bus bars connected to transmission lines. This network has two generators having rating of 124MW and 65MW connected to bus bars 1 and 2 respectively. There are five loads connected to these six bus bars 2, 3, 4, 5 and 6 respectively. There are 20MW, 85MW, 40MW, 20MW, 20MW loads connected to 2 to 6 bus bars in the same order given. No load is connected to the bus bar 1.

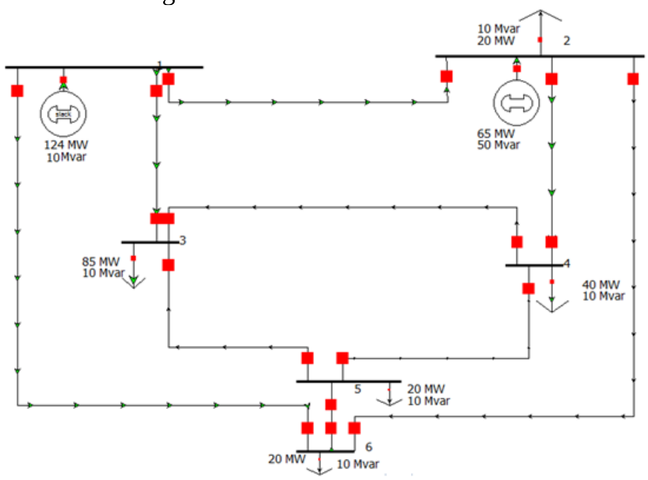

Fig. 1(h) RBTS IEEE network working under normal conditions

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A. Generator 1 out of service

From the figure 1(i) it can be seen that generator 1 is open The generator situated at bus bar 2 supply power to all the loads present in the network. Load present at the bus bar 3 will get the power transmitted from 2 to 4 and from there through 4 to 3. The loads at bus bars 5 and 6 get the power transmitted from 2 to 6 and then from there it is from 6 to 5. The line 1 to 2 is open and no power flow through this and there will be no losses also at this line.

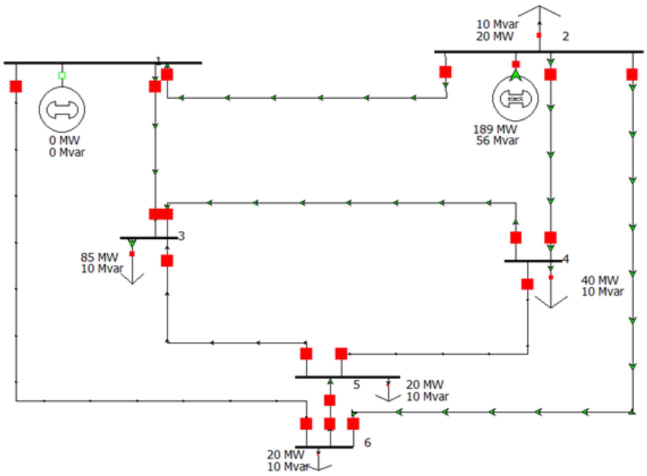

Fig. 1(i) RBTS IEEE system working with generator 1 open

B. Transmission line fault:

In the scenario, the transmission line connected between the bus bar 1 and 2 is disconnected. The power flow will be normal in the line 1-3, 1-6, 2-4 and in the lines 2-6, 3-5, 4-3 and 4-5 is less than the normal.

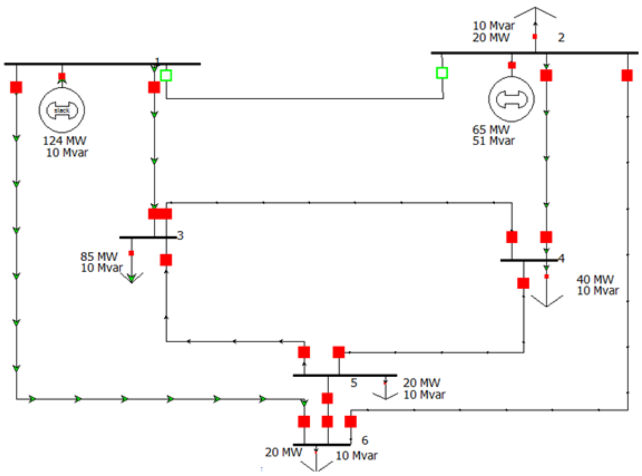

Fig. 1(j) Transmission line 1 to 2 out of service

C. Generator 1 and line 1to 2 out of service

In this scenario, both the generator and the transmission line are out of service. As in the case of normal 6 bus system there are no DGs in the IEEE RBTS 6 bus system. Here when the main thermal generator is off grid then the power is supplied by the second thermal generator present in the grid. As the power required for the loads in the network is not more than the generated power, there is no need of installing the distributed generators near the load centers. Here when one of the generators is not working then the other generator takes over the entire load as long as the power required for the loads is not more than the generation.

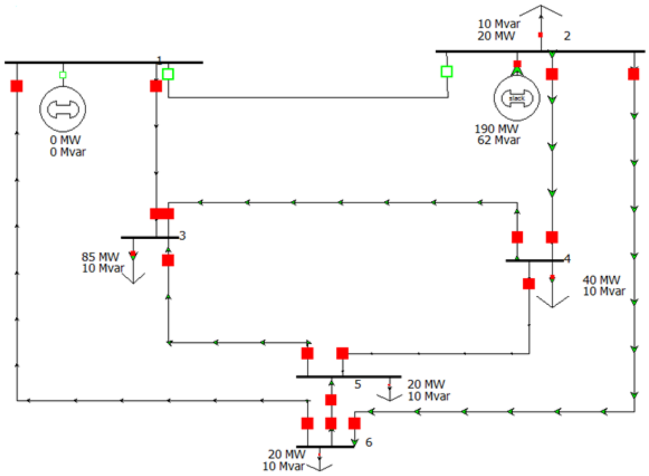

Fig. 1(k) Working of RBTS IEEE network when generator 1 and line 1 to 2 out of service

D. Rerouting in RBTS IEEE network

In RBTS IEEE system the normal operation all the lines connected to the bus bar 1 are closed and the restoration is not needed. It is because in the normal 6 bus system each bus bar is connected to the other bus bar with a transmission line but in IEEE 6 bus system only few lines are connected. From the bus bar 1 the transmission lines are connected to bus bar 2, 3 and 6 only. Under normal conditions, there is no over loading of lines is not happening and so no need of rerouting. If in the case the lines are overloaded another line has to be connected.

E. Analysis of losses in RBTS IEEE network

Table II gives the information regarding the losses incurred in different lines of the network. It can be seen that the losses are very less.

Table II: MW and MVAR losses in RBTS IEEE network

Transmission line	MW losses				MVAR losses			
	Normal operation	Gen 1 open	Line 1 to 2 open	Gen 1 & line 1 to 2 open	Normal operation	Gen 1 open	Line 1 to 2 open	Gen 1& line 1 to 2 open
1 to 2	0.32	0.32	0	0	0.41	0.38	0	0
1 to 3	1.48	0.49	2.1	0.20	5.10	0.04	8.3	1.44
1 to 6	0.51	0	1.0	0.15	0.61	2	3.6	1.16
2 to 4	0.72	1.44	0.5	1.91	2.49	6.33	1.4	8.83
2 to 6	0.16	0.97	0.1	1.70	0.54	3.38	0.3	5.92
3 to 4	0.05	0.22	0.2	0.35	1.02	0.09	1.1	0.64
3 to 5	0.06	0.15	0.4	0.21	0.97	0.47	1.0	0.14
4 to 5	0	0.01	0	0.02	1.30	1.24	1.2	1.15
5 to 6	0.36	0.4	0.3	0.42	0.57	0.79	0.5	0.95

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V. CONCLUSION

In this project a deep discussion is done over simulation in PWS. The main aim of this project is to make automatic restoration of the network. This method detects the fault in the line and automatically diverts the power flow to the other transmission line. If in the case the generator is out of service due to any reason the nearest generator is identified and connected to the grid. A mesh connected system is designed in PWS and different conditions have been checked. The project is done for both normal 6 bus system and also the RBTS IEEE 6 bus system. In this two solutions are proposed one is installing distributed generators and the other rerouting of transmission lines. The same test when done ON grid that would result in loss of many equipments and loss of money. By testing in PWS the cost is reduced and it can be applied to grid afterwards.

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