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# PARTIAL MODEL DEVELOPMENT OF POWER GRID STRUCTURES CONSIDERING SECTIONALIZING SCENARIOS FOR THE CONTROLLING ELECTRIC SYSTEM EXPANSION

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Abstract. *Nowadays, power system modeling approaches become important strategies for developing, designing, and expanding the real system. Many physical systems are analyzed and evaluated using appropriate models. Presently, renewable energy sources inclusion in the power system also becomes one of the major issues in the sustainable energy operation and environmental penetration. By considering potential sources, many local power grids are expanded to accept the renewable energy technology in the daily operation. This paper presents a power flow evaluation for assessing a partial power grid model of the expanded classical system. These studies also explore thunderstorm algorithm to obtain the power balance commitment while the optimal power flow is defined using artificial salmon tracking algorithm. Results show that the renewable energy sources affect the system performances. Both algorithms can be applied to the hybrid structure model to searching the operating condition with smooth performances.*

**Keywords:** Power grid, Renewable energy, System performance, Thunderstorm algorithm

1. **Introduction.** In simple words, a power system (PS) is modeled as a network between an energy producer and an energy user where the power delivery is serviced through a power line. By considering this principle, an integrated network of the PS is developed in a huge interconnection which is divided in terms of generation, transmission, distribution, and utilization systems [1-4]. In particular, all of the section has a partial contribution and function as long as it joins in the system operation. This integration should be maintained regularly to keep the PS in secure condition based on technical requirements. In detail, the generation system is used to produce power outputs at various generating units where a primary energy form is converted into electricity considering technical limitations. The transmission system is operated in an interconnected structure as multiple power lines linked to different substations considering voltage level changes. This system is also used to decrease a power loss for the long distance of final energy users. Moreover, the distribution system delivers the power to users where the power is distributed through a certain line topology considering the voltage conversion to the lower levels. These voltage levels are very useful to divide the system into a regional operating system based on the covered area of the interconnection system. The utilization system is energy users as the final load that consumes the power for various appliances or apparatus. This utilization consists of many types of the load demands which can be characterized in leading and lagging load types [5,6].

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Nowadays, the power grid structure has been developed in a very large network consisting of many types of power plants, huge networks, and various loads [7-10]. This network can be adopted from various topology models or designed systems. This network is also used to join all generating units located at different closely primary energy sources. Moreover, this network is connected to the load centers at different distances for the power delivery. In addition, this network is composed using many parts and sections for the existing PS with high reliability. These parts and sections should be managed and operated in a high reliable coordination to keep the system in a stable condition. In fact, the PS is also used to join load centers that span large distances and also deployed over decade systems where the PS is divided into several areas of the operation [9,11,12]. This cascade model is provided for the voltage classification which is used to supply power demands in many areas. Each area has a local power grid system (LPGS) which exists for covering all generating units and load demands. This partial section is developed to increase an operational service and to make an easy management during the operating period for the 24 hour operations. By considering the LPGS, the PS can be controlled and monitored in local systems based on sectional system performances. Moreover, the LPGS is also operated based on the own voltage levels and it is cascaded into the main grid at the backbone system. Technically, to provide high-quality services and to cover disturbances, the PS is operated in an interconnected power grid system (IPGS). This connection is used to make easy an electric system expansion for the future. In detail, many local grids are connected together to become a huge topology of the IPGS which is used to merge a networking of partial systems and physical parts [3]. Recently, the PS continues to become a modernized structure and to combine all of the LPGS which is subjected to increase reliability and capability for the IPGS.

Operationally, the PS is also developed to increase security for providing the high-quality energy selling to meet the power demand growth [13-16]. This security is very important during export and import power transactions while the power flow is delivering through all areas. The increasing secured operation of the PS is an important aspect of the power system severity. The most sensitive problems of the PS are identified using shift factors and interruptible conditions. One of these issues is a sensitive generator which is identified using shifting contingency factors. This issue leads to improving the power grid structure for the quality performances. Moreover, the contingency problems are also recognized to overcome the faulted impacts in terms of connected and disconnected lines, integrated and host load generators, and load demand changes. The most critical aspects of the PS deal with the power system severity presented in generator outage conditions, transmission line loadings, and bus voltage magnitudes. The PS is also monitored in steady-state and transient conditions for defining normal and under faulted performances [17-19]. In general, the power system performance (PSP) is used to identify the measuring power availability and to identify voltage sags, voltage unbalance, voltage regulation, or harmonic levels. The PSP is also maintained regularly to improve the reliability performance considering the optimal operating condition, and the system, is subjected to small and large disturbances. By considering these conditions, the PSP is assessed using a power flow method (PFM) for defining and identifying the operating status of the system.

Many methods have been proposed and applied to power flow studies. These approaches are used to evaluate the integrated and partial performances of the loads, power lines, and generating units. In general, the load demand is growing up a deal with the produced power availability and networking capacities of the PS. The power availability faces exploring potential primary sources. In nature, a non-fossil energy source is called in a renewable energy source (RES). Technically, the RES usages depend on applied current technologies for producing the power output [4,20-24]. In these cases, wind and solar sources are the popular sources of the RES caused by freely accessible, cost competitive and environmentally friendly. Many models have been proposed to cover the RES implementation. Moreover, the various alternative energy sources are integrated into the generation mix in various power grids. This paper presents the PSP assessment considering an additional power source into the LPGS caused by potential natural sources and a possible implementation to face the load demand growth. The system model is subjected to the solar energy injection into the LGPS through the solar cell module. These studies also explore the PSP through the latest computational approaches in terms of thunderstorm algorithm (TA) and artificial salmon tracking algorithm (ASTA).

2. **Power Grid Performances.** As mentioned before, the PS is evaluated and measured using technical performances for identifying the system condition. The model is assessed to know the operating status under all requirements [9,25-28]. Many techniques have been proposed and applied to the PS whereas the popular approaches are Newton-Raphson and fast decouple [9,29-31]. Technically, the PSP is evaluated using a power flow study (PFS). This study is an important aspect of the future planning expansion and it is used to determine the optimal operation of the PSP. In general, the PFS is the most important approach to determine optimal performances on the PFM. This analysis can provide a balanced steady-state operation of the PS. In detail, each bus is classified into three types of the load bus, generator bus, and swing bus [29-34]. Load bus called in P-Q bus is defined that a bus where the real and reactive power is specified, and the bus voltage will be calculated. Generator bus called in P-V bus is a bus with the magnitude of the voltage defined and kept constant by adjusting a generator. A slack bus called in swing bus is a special bus which is operated as the reference bus. The voltage is assumed to be fixed in both magnitude and phase for the swing bus. In these studies, the PFS will be developed using thunderstorm algorithm (TA) and Takagi method (TM) to make a combined technical problem statement. In this problem, TA is used to search a suitable portion of generating units based on the contributing portion rate which is defined using TM. Moreover, structures and intelligent agents of TA are discussed completely in previous works while the effectiveness of the TM for the PFS is also reported clearly in [23,33,35-37].

Recently, the generating unit fossil fuel based is faced with the environmental requirement for the daily operation of the PS and it also meets the demand growth for safety, reliability, and quality. The trends in the energy generation, as well as consumptions, are increasing steadily all over the users due to the growing population and remarkable industrialization. The growing up population leads to the energy consumption which corresponds to the power plant production. In addition, the current commercially available energy storage systems are neither technically nor economically feasible for the bulk energy storage covering the RES [20]. As the global warming impacts and environmental awareness, the RES becomes potential issues to be implemented and mitigated for the alternative power sources. Moreover, these natural sources also become cost competitive in comparison with fossil-based sources. Declining traditional fossil fuel energy resources combined with carbon emissions restrictions and environmental protection policies are compelling operators to reduce their fossil fuel combustions [16,23,33,37-39]. In fact, the RES application depends on current technologies for the produced power output. The inclusion of the RES as a distributed generation is challenge and respect issues for referring to the quality of supply, stability of the network, system balancing, voltage regulation, protection, failure, and reliability. This inclusion becomes an opportunity for the PSP model considering the RES and it should be conditioned in the optimal operation. In detail, the PFS accommodates all technical constraints and requirements which are integrated in the optimal power flow problem carried out using ASTA. In principle, ASTA is compiled using its procedures based on the exploring and surviving steps of the salmon fish migration. The exploring step is used to search out a mouth river for guiding a desired possibility selection. The surviving step is used to find out the returning destination to track the desired solution at all various branches [10]. By considering the RES, the PFS is approached using a power injection strategy into the system which is used to control the power balance between power producers and load demands covering a power loss of the lines. In general, the performance of the PFS is formulated using the following expressions:

$$PG_p + P_p^{add} = PD_p + V_p \cdot \left[ \sum_{q=1}^{nBus} V_q \left( G_{pq} \cdot \cos\left(\theta_{pq}\right) + B_{pq} \cdot \sin\left(\theta_{pq}\right) \right) \right], \tag{1}$$

$$QG_p + Q_p^{add} = QD_p + V_p \cdot \left[ \sum_{q=1}^{nBus} V_q \left( G_{pq} \cdot \sin(\theta_{pq}) - B_{pq} \cdot \cos(\theta_{pq}) \right) \right], \tag{2}$$

$$P_i^{\min} \le P_i \le P_i^{\max}, \tag{3}$$

$$Q_i^{\min} \le Q_i \le Q_i^{\max}, \tag{4}$$

$$V_p^{\min} \le V_p \le V_p^{\max}, \tag{5}$$

$$S_{pq} \le S_{pq}^{\max}, \tag{6}$$

where $PG_p$ and $QG_p$ are power injections of load flow at bus $p$ (MW and MVar), $P_p^{add}$ and $Q_p^{add}$ are the additional power injections at bus $p$ (MW and MVar), $PD_p$ and $QD_p$ are load demands of load flows at bus $p$ (MW and MVar), $V_p$ and $V_q$ are voltages at buses $p$ and $q$ (kV), $P_i^{\min}$ and $P_i^{\max}$ are the minimum and maximum power outputs (MW) of the $i^{\text{th}}$ generating unit, $Q_i^{\max}$ and $Q_i^{\min}$ are maximum and minimum reactive power outputs (MVar) of the $i^{\text{th}}$ generating unit, $Q_i$ is the reactive power output of the $i^{\text{th}}$ generating unit (Mvar), $V_p^{\max}$ and $V_p^{\min}$ are maximum and minimum voltages at bus $p$, $S_{pq}$ is the power transfer between buses $p$ and $q$ (MVar), and $S_{pq}^{\max}$ is the limit of the power transfer between buses $p$ and $q$ (MVar).

3. **Partial Model Development.** In general, the PS can be divided into several areas which are managed easily to monitor and control the power production, power transaction, and power consumption. These sectioned areas are integrated to become an interconnected network as the LPGS for delivering electricity from producers to consumers [14,34,40,41]. The PS is developed using partial models of the large network consisting of power plants, huge networks, and various loads. In general, power stations may be located near a primary energy source. It is also located away from heavily populated areas. Recently, the PS is divided into the LPGS whereas a distributed power plant can be installed closely at the load center [4,22,42,43]. This model is used to gain the operating sections in suitable ranges and levels for the loads. By considering the LPGS, it is an important issue to include the RES and to cover the sustainable energy growth recognition in the PS. The inclusion of the RES in the PS expansion ensures decreased dependency on fossil fuels in the future. The fossil fuel consumption is penetrated by an environmental protection for reducing pollutant emissions. The most popular of the RES is subjected to applicable technologies. Refer to these potential sources, solar and wind energies are more popular than other primary energy sources [40,44,45].

In these studies, the solar power is incorporated into the LPGS. The integration of the solar power is supposed to contribute to the unit commitment of the power production.

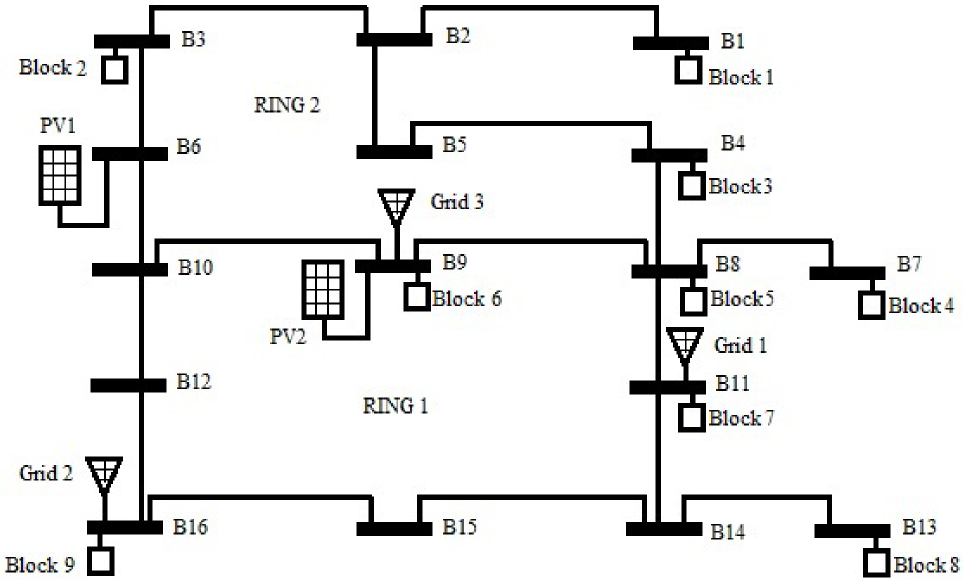


FIGURE 1. Power grid model of electric system expansion

Moreover, Figure 1 shows a model of the LPGS covering a solar power plant (SPP). This topology is used to improve the electric system expansion based on the 20 kV system and to re-design the configuration of the LPGS. This expansion is very important to meet the demand growth over the existing period of the operation. This re-configuration also increases the energy stock and system capability by an installation of the RES through the SPP and power line reinforcement [46,47]. Moreover, Figure 1 illustrates the expansion of the State University of Malang Power Grid System (SUMPGS). The SUMPGS is re-designed on the backbone system of 20 kV. Operationally, this model is connected to the Malang Raya Power Grid System linked to the Java Bali Power Grid. In addition, this model is also prepared for the 70 kV integrated system.

By considering the backbone system of 20 kV, the SUMPGS is structured in the Ring 1 and Ring 2. The Ring 1 is developed to modify the radial system becoming a mesh model of the system. This type is re-designed from the original topology that covers all incoming power grids. The Ring 1 of the partial power grid integrates all load buses at covered locations. Future developments and potential sources are mandatory plotted in the Ring 2. The Ring 2 is developed from the Ring 1 by completing the RES at the possible locations where the potential areas are possible to be the RES centers. At these locations, the SPP is installed at the Bus 6 and Bus 9. As mentioned before, the SUMPGS developed on 20 kV is also prepared for connecting to 70 kV. The SUMPGS is expanded in several additional load blocks as given in Figure 1. These loads are distributed at several buses for the Ring 1 and Ring 2. Based on Figure 1, all lower voltage loads are integrated to 20 kV at the close buses. The lower voltage systems cover all spatial system of 220 V.

4. **Procedures of Sectionalizing Scenarios.** As discussed before, the PS is evaluated and measured to identify technical performances of the system condition. In general, this evaluation is used to know the operating status through a power flow analysis. Moreover, the PFS is commonly used in the power system evaluation to define the optimal operation of the PS. Based on this purpose, the PFS is the most important approach to determine the operating performances of the system. In these works, Figure 1 is a reference for a sectioning electricity system divided into two areas for Ring 1 and Ring 2. Based on this

figure, the SPP is installed at selected potential buses associated with a designed space of the RES. In detail, the SUMPGS is structured using 16 buses, 17 lines, and 9 load buses, and 2 solar power centers. By considering Figure 1, the sectionalizing scheme (SS) is designed in three schemes for the LPGS. The SS is presented in the original system evaluation (OSE) as given in Figure 2, expanded connection system evaluation (ECSE) as given in Figure 3, and solar power integrated evaluation (SPIE) as given in Figure 4. The OSE covers only Ring 1 while the Ring 1 and Ring 2 are covered in the ECSE without the SPP, and all conditions of the system are integrated in the SPIE. In detail, the SS is applied to all possible networks as illustrated in Figure 2, Figure 3, and Figure 4. Furthermore, technical data for these works are given in Table 1, and Table 2.

In these studies, the SS considers Figure 2, Figure 3, Figure 4, Table 1, and Table 2. Figure 2 shows the system topology of the original power system structure before expanding to the double ring type as detailed in Figure 4. Moreover, Table 1 consists of power line parameters of conductors which are used to connect each bus of the designed system while the partial loads are listed in Table 2 for the Ring 1 system and the Ring 2

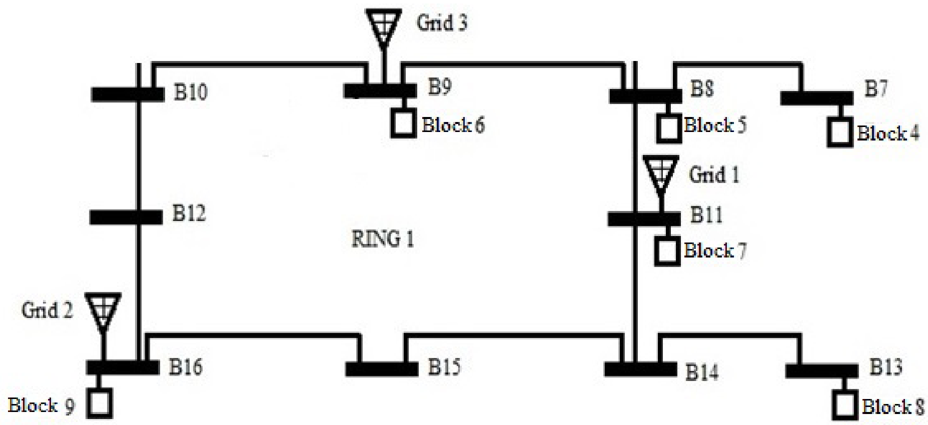


FIGURE 2. Original system evaluation (OSE) model

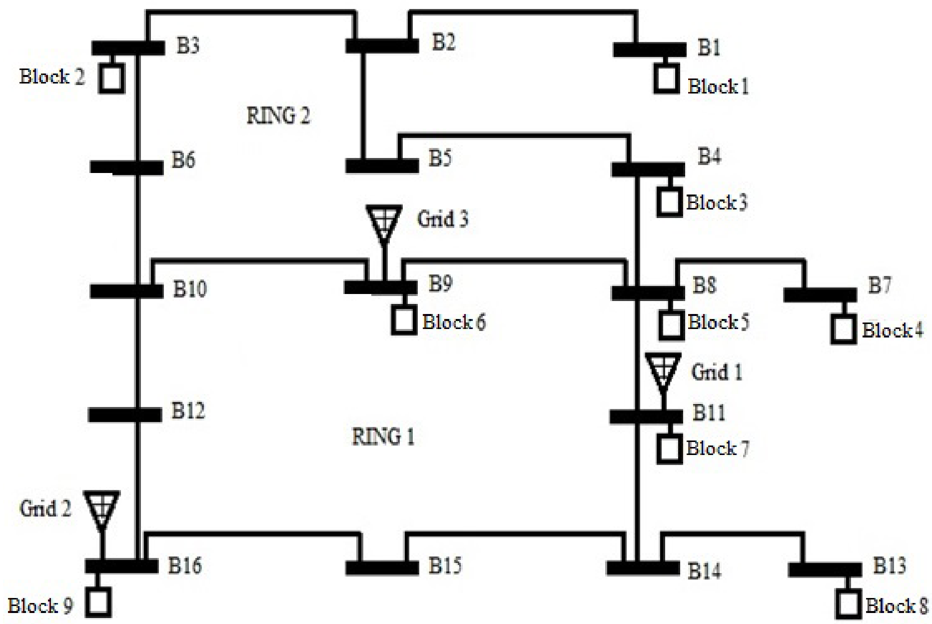


FIGURE 3. Expanded connection system evaluation (ECSE) model

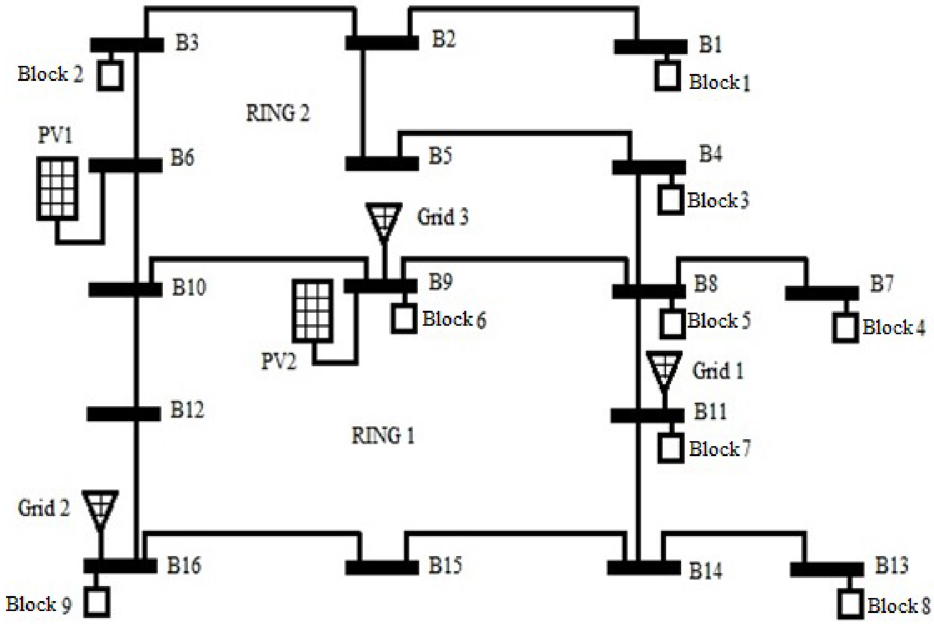


FIGURE 4. Solar power integrated evaluation (SPIE) model

TABLE 1. Powerline parameters of the LPGS

| No | Route | From | To | Type | Length (ft) |
|---|---|---|---|---|---|
| 1 | Track 1 | B7 | B8 | Cable | 459.32 |
| 2 | Track 2 | B4 | B8 | Cable | 656.17 |
| 3 | Track 3 | B6 | B10 | Cable | 984.25 |
| 4 | Track 4 | B10 | B12 | Cable | 426.51 |
| 5 | Track 5 | B12 | B16 | Cable | 590.55 |
| 6 | Track 6 | B1 | B2 | Cable | 820.21 |
| 7 | Track 7 | B2 | B3 | Cable | 787.40 |
| 8 | Track 8 | B9 | B10 | Cable | 557.74 |
| 9 | Track 9 | B8 | B9 | Cable | 269.03 |
| 10 | Track 10 | B15 | B16 | Cable | 688.98 |
| 11 | Track 11 | B14 | B15 | Cable | 459.32 |
| 12 | Track 12 | B13 | B14 | Cable | 524.93 |
| 13 | Track 13 | B3 | B6 | Cable | 623.36 |
| 14 | Track 14 | B8 | B11 | Cable | 209.97 |
| 15 | Track 15 | B11 | B14 | Cable | 308.40 |
| 16 | Track 16 | B4 | B5 | Cable | 328.08 |
| 17 | Track 17 | B2 | B5 | Cable | 492.13 |

system as located in Figure 1. Referring to this topology and data of the LPGS, the PFS is subjected to find out the optimal performances based on the OSE, ECSE, and SPIE. In addition, the TM is applied to covering the PSP for the PFS as detailed in [35,36] while TA is used to find out the power balance and ASTA is applied to searching for the optimal power flow. Technically, the PFS is constrained by 10% of the loss limit on the power lines. The suitable operation is desired in $\pm 5\%$ of voltage violations. The power delivery on the power lines is required in 95% of the power transfer capability. In these works, TA and ASTA refer to detailed procedures and hierarchies in [10,23,33]. Based

TABLE 2. Partial load conditions of the LPGS

| Ring 1 System | | | | | |
|---|---|---|---|---|---|
| Bus | kVA | kV | kW | kVar | % PF |
| B7 | 1,478 | 20 | 838.00 | 49.06 | 87.00 |
| B8 | 1,653 | 20 | 937.00 | 54.84 | 87.00 |
| B9 | 2,176 | 20 | 823.00 | 67.15 | 93.53 |
| B11 | 1,044 | 20 | 592.00 | 34.64 | 86.99 |
| B13 | 1,043 | 20 | 592.00 | 34.63 | 86.99 |
| B16 | 2,044 | 20 | 759.00 | 62.93 | 93.75 |
| Total | 9,438 | | 9,438.00 | 4,541.00 | |
| Ring 2 System | | | | | |
| Bus | kVA | kV | kW | kVar | % PF |
| B1 | 1,500 | 20 | 1,301.00 | 738.00 | 86.99 |
| B3 | 2,912 | 20 | 2,733.00 | 984.00 | 94.09 |
| B4 | 1,700 | 20 | 1,477.00 | 837.00 | 87.00 |
| Total | 6,112 | | 5,511.00 | 2,559.00 | |

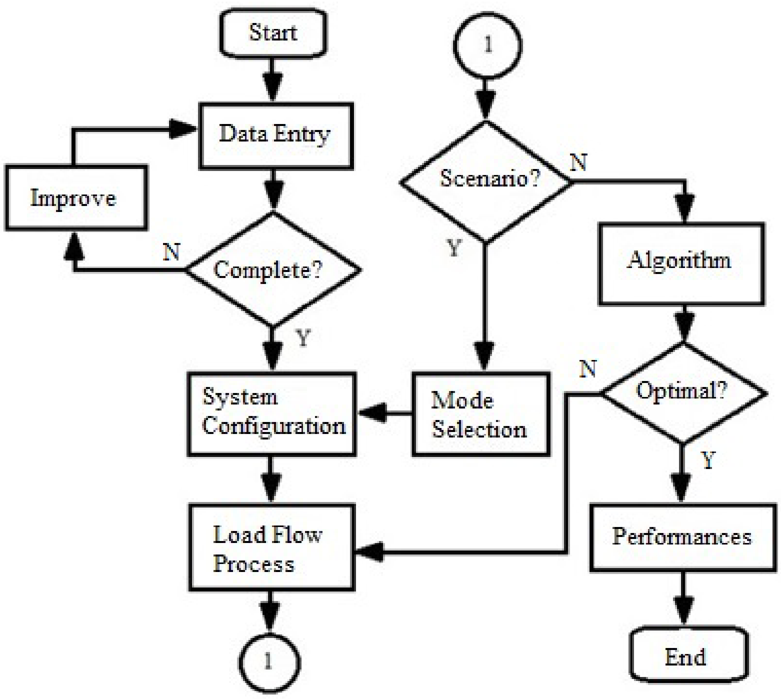


FIGURE 5. Computational procedures of the sectionalizing evaluation

on these principles, the programs of TA are run in 1 of the avalanche, 50 of the cloud charge, 100 of the streaming flows, 4 of the hazardous factor, and 200 of the cloud size. Furthermore, ASTA is presented using 100 of salmon number, 0.25 of a surviving factor, 100 of mouth river, 100 of tracking round, 1 of the migrating period, and 50 of solution population. Specifically, performances of TA, ASTA, and TM are not detailed in these studies whereas these works are concerned in the PSP for the SS of the LPGS. Based on parameters of TA and ASTA data needed, the procedure is illustrated in Figure 5. This figure gives a hierarchy for defining and evaluating the SUMPGS based on 20 kV. The sequencing orders for this figure cover data entry, load process, TA, and ASTA. The TM is included in the PFS model.

5. **Results and Discussions.** In this section, these works are addressed to evaluate the performances of the LPGS considering the RES for the SPP based on the SS. In detail, the final expansion is presented in Figure 6 covering for the load positions and renewable energy plants accompanied by the grids. The SPP is installed at two buses as the captive power centers. Based on Figure 1, the SS is designed in the OSE, ECSE, and SPIE for covering the Ring 1 and Ring 2. By considering the OSE, the LPGS feeds the total load of 10,473.61 kVA for 9,438.00 kW and 4,541.00 kVar. In particular, the ECSE and SPIE provide power productions to meet the same load. The loads are given in 14,122.08 kVA, 10,506.00 kW, and 9,437.00 kVar. In detail, partial loading buses are listed in Table 3 associated with each bus. The impacts of the RES injection are detailed in Table 4 and Table 5. These tables consider the SPP installed on selected buses whereas Table 4 shows the bus condition for the voltage, current, and power factor based on the SS. From Table 3, it is known that the load system is also expanded to the several additional loads connected to the bus. In total, these load demand growths are 3,648.47 kVA, 1,648.47 kW, and 4,896.00 kVar.

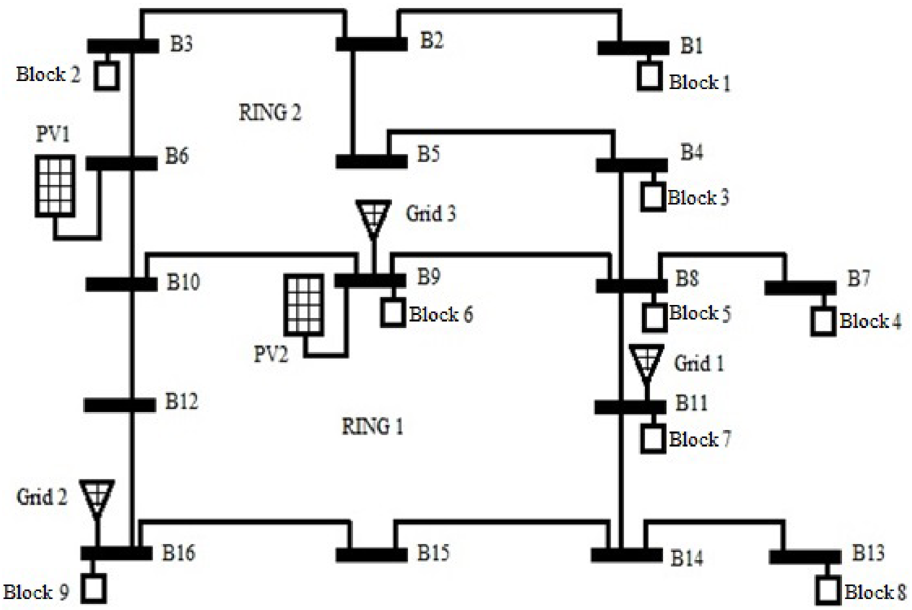


Figure 6. Final structure model of the power system expansion

Table 3. Loading bus of the sectionalizing scenarios

| OSE | | | | ECSE and SPIE | | | |
|---|---|---|---|---|---|---|---|
| Bus | S (kVA) | P (kW) | Q (kVar) | Bus | S (kVA) | P (kW) | Q (kVar) |
| B7 | 1,478.00 | 838.00 | 49.06 | B1 | 1,500.00 | 1,301.00 | 738.00 |
| B8 | 1,653.00 | 937.00 | 54.84 | B3 | 2,912.00 | 2,733.00 | 984.00 |
| B9 | 2,176.00 | 823.00 | 67.15 | B4 | 1,700.00 | 1,477.00 | 837.00 |
| B11 | 1,044.00 | 592.00 | 34.64 | B7 | 1,700.00 | 1,478.00 | 837.00 |
| B13 | 1,043.00 | 592.00 | 34.63 | B8 | 1,900.00 | 1,652.00 | 936.00 |
| B16 | 2,044.00 | 759.00 | 62.93 | B9 | 2,326.00 | 2,176.00 | 823.00 |
| – | – | – | – | B11 | 1,200.00 | 1,044.00 | 592.00 |
| – | – | – | – | B13 | 1,200.00 | 1,043.00 | 592.00 |
| – | – | – | – | B16 | 2,180.00 | 2,044.00 | 759.00 |
| Total | 10,473.61 | 9,438.00 | 4,541.00 | Total | 14,122.08 | 10,506.00 | 9,437.00 |

Table 4. Bus performances of the system

| Bus | OSE | | | ECSE | | | SPIE | | |
|---|---|---|---|---|---|---|---|---|---|
| | I (A) | PF (%) | V (%) | I (A) | PF (%) | V (%) | I (A) | PF (%) | V (%) |
| B1 | 0.00 | 0.00 | 0.00 | 43.24 | 86.99 | 99.85 | 43.24 | 86.99 | 99.86 |
| B3 | 0.00 | 0.00 | 0.00 | 83.96 | 94.09 | 99.88 | 57.68 | 87 | 99.9 |
| B4 | 0.00 | 0.00 | 0.00 | 49.04 | 87 | 99.92 | 49.04 | 87 | 99.93 |
| B7 | 49.06 | 87 | 99.97 | 49.05 | 87 | 99.96 | 49.05 | 87 | 99.96 |
| B8 | 54.84 | 87 | 99.99 | 54.84 | 87 | 99.98 | 54.84 | 87 | 99.98 |
| B9 | 67.15 | 93.53 | 100 | 67.15 | 93.53 | 100 | 72.17 | 86.99 | 100 |
| B11 | 34.64 | 86.99 | 100 | 34.64 | 86.99 | 100 | 34.64 | 86.99 | 100 |
| B13 | 34.63 | 86.99 | 99.98 | 34.63 | 86.99 | 99.98 | 34.63 | 86.99 | 99.98 |
| B16 | 62.93 | 93.75 | 100 | 62.93 | 93.75 | 100 | 34.64 | 86.99 | 100 |
| Total | 303.25 | | | 479.48 | | | 429.93 | | |

Table 5. Branch performances of power lines

| Bus | | OSE | | | ECSE | | | SPIE | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | V Drop | Loss | | V Drop | Loss | | V Drop | Loss | |
| From | To | (%) | kW | kVar | (%) | kW | kVar | (%) | kW | kVar |
| B7 | B8 | 0.02 | 0.23 | 0.30 | 0.02 | 0.23 | 0.30 | 0.02 | 0.23 | 0.30 |
| B4 | B8 | 0.00 | 0.00 | 0.00 | 0.06 | 1.40 | 1.84 | 0.05 | 1.10 | 1.44 |
| B6 | B10 | 0.00 | 0.00 | 0.00 | 0.06 | 1.07 | 1.41 | 0.05 | 0.68 | 0.89 |
| B10 | B12 | 0.00 | 0.00 | 0.00 | 0.01 | 0.06 | 0.08 | 0.01 | 0.04 | 0.05 |
| B12 | B16 | 0.00 | 0.00 | 0.00 | 0.01 | 0.08 | 0.11 | 0.01 | 0.05 | 0.07 |
| B1 | B2 | 0.00 | 0.00 | 0.00 | 0.03 | 0.31 | 0.41 | 0.03 | 0.31 | 0.41 |
| B2 | B3 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.03 | 0.00 | 0.00 | 0.00 |
| B9 | B10 | 0.00 | 0.00 | 0.00 | 0.02 | 0.25 | 0.33 | 0.02 | 0.16 | 0.21 |
| B8 | B9 | 0.01 | 0.11 | 0.15 | 0.02 | 0.45 | 0.59 | 0.02 | 0.40 | 0.52 |
| B15 | B16 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 |
| B14 | B15 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 |
| B13 | B14 | 0.02 | 0.13 | 0.17 | 0.02 | 0.13 | 0.17 | 0.02 | 0.13 | 0.17 |
| B3 | B6 | 0.00 | 0.00 | 0.00 | 0.04 | 0.68 | 0.89 | 0.03 | 0.45 | 0.59 |
| B8 | B11 | 0.01 | 0.15 | 0.19 | 0.02 | 0.57 | 0.75 | 0.02 | 0.51 | 0.67 |
| B11 | B14 | 0.01 | 0.05 | 0.06 | 0.01 | 0.05 | 0.06 | 0.01 | 0.05 | 0.06 |
| B4 | B5 | 0.00 | 0.00 | 0.00 | 0.01 | 0.19 | 0.25 | 0.01 | 0.12 | 0.15 |
| B2 | B5 | 0.00 | 0.00 | 0.00 | 0.02 | 0.29 | 0.38 | 0.02 | 0.17 | 0.23 |
| | | | 0.69 | 0.89 | | 5.80 | 7.62 | | 4.42 | 5.78 |

Based on Table 4, it is known that the OSE, ECSE, and SPIE have different performances. Totally, the least current is supplied by the OSE in 303.25 A while the highest one is delivered by the ECSE which is accumulated in 479.48 A. In reference, the SPIE provides 429.93 A where 49.55 A is contributed from the SPP. These results indicate that the smallest current consumption is absorbed in Bus 13 or it is used for the load demand at Bus 13 or Block 8 around 34.63 A. This condition is similar to the SPIE scheme. Another schema shows that the ECSE has a minimum current usage in 43.24 A for the Bus 1. In particular, load performances are detailed in 86.99%-94.09% of the power factor where the bus voltage conditions are operated in small fluctuations.

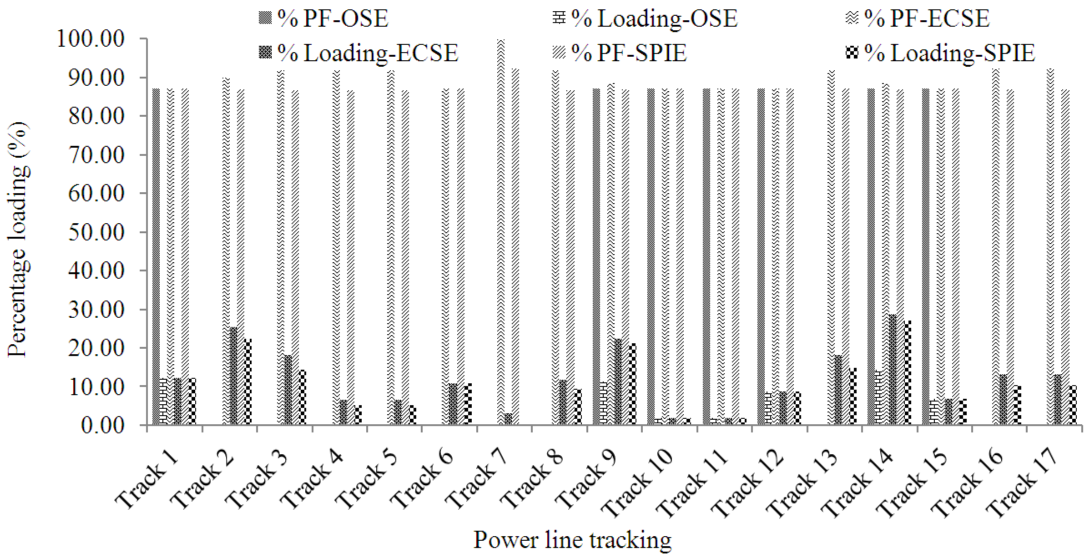


FIGURE 7. Branch loading performances

By considering power deliveries to meet load demands through the PFS, power line performances are given in Table 5 as branch performances. This table is produced based on the power demands as designed in Table 3. Focused on the power loss, the lines absorb the power around 0.69 kW for the OSE. On the other hand, the ECSE is optimized in 5.8 kW while the SPIE lost is 4.42 kW. In general, voltage drops are still under requirement of 10%. Individually, the percentage branch loadings are illustrated in Figure 7 for each bus delivery.

6. **Conclusion.** This paper presents an evaluation of the structure model for the local power grid system considering the solar power plant and sectionalizing schemes for the electric system expansion. In these works, the system is expanded into a double ring topology. The system evaluation is studied in the optimal power flow of the system associated with Takaguchi method, thunderstorm algorithm, and artificial salmon tracking algorithm. All approaches are combined in the designed program which is used to search for the power balance composition and optimal power flow. These works indicate that the solar power plants penetrate the power productions and effect system performances. All implemented technical approaches have an opportunity to apply to the power flow evaluation. For the future works, revealing the computational structures and complicated model are recommended.

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